THE RESOURCES OF THE EMPIRE

A business man's survey of the Empire's resources prepared by the Federation of British Industries.

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GENERAL INTRODUCTION

BY

THE RIGHT HON. SIR ERIC GEDDES, G.C.B.

IN undertaking the preparation of this Series the Federation of British Industries has, I am convinced, rendered a really practical service to business men throughout the Empire.

Hitherto, there has been no standard work of reference giving the information which ought to be in the possession of business men all over the world regarding the resources of Great Britain and the other countries of the Empire in the materials of industry.

It is true that there are some excellent monographs describing in general terms the resources of isolated parts of the Empire, and a very few dealing comprehensively with individual products, but, apart altogether from the fact that the sum total of the information contained in existing publications falls hopelessly far short of what is requisite, such information as exists is hardly prepared in a form adapted to the requirements of the practical man who wants neither a bare table of statistics about the products essential to him in his business nor a mere general description of the extent of the resources of a given country in those products. On the contrary, the business man wants information not only as to the available supplies of his raw materials, but as to the quality of the supplies produced in different parts of the world, as to the amount of the undeveloped resources, as to the transport facilities, as to the local conditions of labour, etc., and as to the chances of present supplies available for import in this country being absorbed in the near future by local demands. In other words, he wants particulars of all those factors which have to be taken into account in the ordinary course of business, and he wants those particulars arranged in an accessible form.

The aim of this Series has been to give this information in this form, and thus to provide not only for our own use, but for the use of traders all over the world, a compendious Buyers' Guide to our Imperial resources. I venture to think that the present is a very appropriate time for this undertaking. It is not only that all our thoughts are being turned towards the idea of Empire trade and Empire development by the great Exhibition which is shortly to be opened, and which will be the most impressive demonstration of our Imperial productiveness that the world has yet seen. The whole trend of economic circumstances is forcing us in the same direction.

The world war has disastrously affected the Continent of Europe as a market for the manufactured goods of Great Britain and the products of the British Dominions. Even foreign countries which were neutral in the great struggle have suffered in the same way, though in a less degree. Our trade

with the Far East and South America has suffered serious diminution, and though more than five years have now elapsed since the cessation of hostilities the resumption of normal conditions seems but little nearer. Moreover, foreign tariffs are rising higher and higher against us all over the world. Meanwhile our own productive capacity has been substantially increased and our population has grown to such an extent that we have now two million more mouths to feed and a million more men to employ than we had in 1914. It seems clear, therefore, that we need some reorientation of our commercial policy, and the obvious direction for this seems to be the cultivation of our own inheritance. A study of the facts shows that there is good hope in such a policy. Britons in all parts of the world are bound together by ties of sentiment and custom which neither distance nor difference of conditions can seriously weaken. Not only has the tremendous investment of British money in our Overseas Dominions bound us with a golden chain: there are a thousand invisible impulses always strengthening the bond. Even in 1913 our trade with the Empire was about 25 per cent. (imports) and 36 per cent. (exports) of our total world trade. The following tables show this in more detail with a comparison with the figures for the latest twelve months available. From these it will be seen that our imports from Imperial sources show a substantial advance over pre-war, the export figures remaining about the same.

PERCENTAGES OF IMPORTS FROM VARIOUS SOURCES.

Consigned from—	*October*, 1922, *to* *September*, 1923.	*Year* 1913.
British India	6·0	6·3
Self-governing Dominions	16·3	13·3
Other British countries (except Hong Kong)	5·3	5·3
Europe	33·2	40·4
United States	19·6	18·4
South and Central America	10·8	10·0
Other countries	8·8	6·3

PERCENTAGES OF EXPORTS (U.K. GOODS) TO VARIOUS DESTINATIONS.

Consigned to—	*October*, 1922, *to* *September*, 1923.	*Year* 1913.
British India	12·2	13·4
Self-governing Dominions	18·0	17·5
Other British countries (except Hong Kong)	5·7	5·4
Europe	34·2	34·4
United States	8·0	5·6
South and Central America	8·8	10·6
Other countries	[illegible]	[illegible]

SUMMARY OF AREA AND POPULATION (1921-22).

	Area (Square Miles).	Population.
Great Britain and Ireland	121,633	47,308,000
Europe	120	234,000
Asia	2,123,418	332,772,000
Africa	3,822,667	50,119,000
America	4,009,996	11,142,000
Australasia	3,278,917	7,795,000
Total	13,356,751	449,370,000

The following table shows the approximate purchases of British goods per head of population for the first three quarters of 1923:

	£ per Head.
India, British	0·2
Federated Malay States	0·5
Australia	7·8
New Zealand	12·3
Canada	2·3
Hong Kong	7·7
Union of South Africa	2·1

The most striking features here are the huge acreage, small population, and large volume of purchase per head of Australasia, and the relatively huge populations and small volume of purchase in the Eastern territories, with Canada and South Africa occupying an intermediate position. I will recur to this contrast later.

Finally, a few figures may be given indicative of the percentage of various important world supplies either produced or available within the Empire:

	1915.	1921.
Copper (long tons)	100,000	46,000
Percentage of world production	10·2	8·5
Lead (long tons)	—	199,400
Percentage of world production	—	22·9
Tin ore (long tons)	68,300	46,800
Percentage of world production	53·9	42·2
	1913.	1923.
Wool (including alpaca, etc.) (lbs.)	5,414,067	14,077,339
Percentage of world production	74·6	77·1

It is clear, therefore, that there is an almost unlimited field for expansion of our Empire trade, whilst in many lines this possibility of a self-supporting Empire should be realizable. On the side of Great Britain the requisite productive power already exists. Overseas the position is somewhat different, and it seems clear that the requisite development of the purchasing power of the Overseas Dominions can only be produced by a gradual development of the resources of those Dominions, the surest way to which will be an increase in our own consumption of their products. There are two distinct problems, one for the tropical and one for the temperate and subtropical countries.

In the former any substantial increase in the white population is hardly to be expected, since the bulk of the work of the country must in such climates always be done by the native races. The purchasing power of these territories can therefore only be developed by the steady development of their material

resources. This, of course, means recourse to British capital, if Great Britain is to get the greatest advantage from the development and if our Imperial ideal is to be fulfilled. In our present economic condition this, of course, presents some difficulty, but if we can carry out this programme, there will follow a greater demand for British plant, machinery, shipping, rolling stock, etc., as well as a gradual increase in the consuming power of the natives.

In the temperate climates the quickest means to both our objectives lies in the speedy increase of the white populations. Nothing is more striking in the figures given above than the quantity of British goods purchased per head of these great peoples. But it is useless to attempt to stimulate emigration from this country to the Dominions unless there is a real demand for the services of the migrants when they arrive. Such a demand will only arise *pari passu* with the development of the resources of the country concerned.

The deduction to be drawn from the above considerations is obvious. How the required results are to be pursued is a more difficult question. This is not the place, nor am I the person, to embark on questions of political controversy. I will only point out that, whatever method be adopted, accurate and comprehensive knowledge of the facts is absolutely essential. (All those who are engaged in business, either here or overseas, whether it be in finance, in production, in merchanting, in transport, or in insurance, should be informed of what the different parts of our great Empire can produce, and the conditions under which production must take place and those under which the produce can be brought to market. There should be a general knowledge, too, of the amount of foreign competition with which our products and materials have to contend.)

In all my experience, whether on the railways, in the turmoil of the Great War, in Government, or in commerce, I have been continually impressed with the vital importance of accurate and comprehensive statistical knowledge—and, I am afraid, too often impressed with the difficulty of getting it.

This Series is an endeavour to supply such information regarding our Imperial resources. It cannot, unfortunately, be maintained that the results are in every case all that one could wish. However, this very inadequacy is perhaps the clearest justification for the series. The fact that complete information cannot be given shows how necessary it is that all available information should be collected and made public. Only in this way can attention be called to what is wanting and the deficiencies made good. If the Series proves as successful as I hope it may, and believe that it will, it should become a permanent institution, and it should be possible gradually to make good what is now wanting in future issues, so that eventually we may have in it a standard work of reference, which should be indispensable to all those interested or engaged in Imperial commerce or development, whether he be business man, student, or administrator.

March, 1924.

INTRODUCTORY REVIEW

BY

ARTHUR DORMAN

At first sight it may seem a little anomalous to include in a Series dealing with " raw materials " a volume on " Iron and Steel," for in one aspect iron and steel is a finished product resulting from the treatment of such raw materials as iron ore, limestone, coal, etc. But in another and very important sense iron and steel may be looked upon as the raw material for many other industries. It is the raw material, for instance, of shipbuilding, and without the steel ship the foreign and colonial trade of Great Britain could not have reached its present dimensions; it is the raw material for the railways, and without steel rails, sleepers, fishplates, and steel plates for the locomotives, it would be impossible for the interior of our Dominions to be penetrated and settled. The agriculturist depends upon iron and steel for his plough, harrow, sickle, etc., and even for garden implements. The pioneer will be kept comfortably housed by means of galvanized iron until he is able to build a more substantial dwelling for himself, while much of the product of his labour, such as fruit, fish, meat, etc., can only be placed at the disposal of consumers in the home country by means of the tins the cheap production of which is rendered possible by the vast output of the tin-plate industry, which coats very thin sheets of steel with a film of tin.

Countless other ways in which iron and steel contribute to the development of the Empire will readily occur, so that a volume devoted to iron and steel is really very appropriate in a Series devoted to the consideration of the resources of the raw materials of the Empire. From necessity the volume contrasts with some of the other volumes in the Series, in devoting a larger proportion of its space to a consideration of the industry and its products in the home country than in the Empire, but the younger iron and steel industries of the Dominions are not overlooked and the possibilities of their further development fully considered. Perhaps I may say here, on behalf of the iron and steel manufacturers of this country, that we shall give any assistance that lies in our power to the building up of iron and steel industries in the Dominions, for we recognize that the Dominions will wish to develop industrially as well as agriculturally. The need for each Dominion being able on emergency to provide steel as material for self-defence must also not be overlooked.

Considered as a finished product the manufacture of iron and steel gives employment to some 300,000 people in the United Kingdom, while considered as a raw material for shipbuilding, engineering, constructional work, railway material, etc., it provides employment for about 1,700,000 more.

The value of the exports of iron and steel in 1923 amounted to over £76,000,000, and was second only to the value of exports of cotton. The output

of the iron and steel industry, therefore, plays a large part in enabling this country to obtain the essential foodstuffs and raw materials from abroad. Approximately one-half of the product of the iron and steel industry is exported, and approximately one-half of the exports of iron and steel are sent to the British Dominions.

The first essentials for a successful iron industry are supplies of iron ore and of coal in relatively accessible positions. Early in the eighteenth century when the existence of the British iron trade was thought to be threatened by the competition of the American Colonies, Sweden, and Russia, a pamphlet was written entitled *The Interests of Great Britain in Supplying Herself with Iron*, in which the writer stated that " iron ore is a mineral that abounds in most parts of the earth, and there is no considerable tract of this globe wherein it may not, in some shape or other, be found." But at that time " Cumberland and Lancashire are supposed to be capable of answering the purposes, not only of this nation, but even of the Universe." The truth of the assertion as to the abundance of iron ore has since been fully proved, and geologists tell us that iron forms 4·44 per cent. of the earth's crust, a proportion exceeded only by oxygen, silicon, and aluminium. Fortunately, however, it is not evenly distributed, and in some parts of the earth's surface, ore containing as much as 70 per cent. of iron is found, and any part of the earth's surface containing more than 20 per cent. is referred to as iron ore. It is interesting to note that of the total world production of metals, pig iron is over 95 per cent., or twenty times that of other metals combined, and sixty times that of lead, which is the metal produced in the next largest quantity.

While many books have been devoted to the fascinating history of the iron trade, I do not remember a volume describing the products of the industry in such a way as to be helpful to the purchaser of iron and steel since Mr. H. J. Skelton published his excellent little book some thirty-three years ago. There was, therefore, a real need for a volume which would describe the products of the industry, and I am glad that Messrs. Benn arranged to include such a volume in their Series. As long ago as 1854, one of the earliest historians of the Iron and Steel Industry wrote : " There is no subject more important to the country than the success of the iron trade, and whatever cause may tend to affect the position to which we have once attained, it cannot but be a matter of general interest." If true when Scrivenor, the historian referred to, wrote, when the output of iron was under 3,000,000 tons per annum, the statement is even more true to-day, when the country has a capacity for upwards of 10,000,000 tons of pig iron and 12,000,000 tons of steel. That the industry is faced with big problems in the competition from America and the Continent is obvious, but the fundamental physical conditions which enabled a great industry to be built up in this country and to be maintained over a long series of years remain substantially unaffected. We are still the only steel-producing country with suitable coal supplies on the coast to which foreign ore can be brought by sea and the product reshipped, and I for one am confident that Great Britain will retain its position.

ARTHUR DORMAN.

March, 1924.

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INTRODUCTION

It is appropriate that, in a series on the Resources of the Empire, a volume should be devoted to iron and steel, for, although so far the iron and steel industry in the Dominions has not attained very large dimensions, it is safe to say the Empire could not have attained its present stage of development without the aid of the iron and steel resources of the Mother Country. The task of writing such a volume, however, is no easy one, not from any lack of available data, but from the very opposite cause. It is, in fact, a case of *embarras des richesses*, for the literature on iron and steel is expanding every day.

When it is stated that the publishers of this volume have made arrangements to publish a work dealing with one aspect of the industry alone—namely, blast furnace practice—in three volumes, each of which is to be bigger than the present volume; that the well-known work of Professor Howe on the "Metallurgy of Steel and Cast Iron" contains an index of 350 names of those who have contributed to our knowledge of that subject; and that the library of the Iron and Steel Institute runs to over 12,000 volumes, exclusive of pamphlets and periodicals, it will be seen how absolutely impossible it is to collect and collate the vast amount of information that has been published on the subject. Readers desiring more detailed and technical information than is here available will therefore turn to the works of Harbord and Hall, H. M. Howe, Roberts-Austen, and others too numerous to mention.

In the present volume, after a brief historical sketch which brings the industry down to the present day, and chapters dealing with the raw materials of the industry both within and without the Empire, chapters are devoted to the principal products of the industry, dealing with their manufacture, properties, tests, uses, etc.

These chapters have either been contributed by an authority on the subject or the Editor has had the advantage of the collaboration of an authority. It is hoped in this way to give those whose business it is to deal in or to use the products of the iron and steel industry not only a better appreciation of the particular commodity with which they are concerned, but also a better appreciation of the industry which exists to serve them and of the part it plays in the economic life of the Empire.

CHAPTER I

HISTORICAL SKETCH

The properties of iron, as described by Dr. Ure in his *Dictionary of Arts, Manufactures, etc.*, are often quoted, and, except that modern processes have enabled the metal to be produced in quantities undreamed of in his time, are

equally true to-day. " Every person," says he, " knows the manifold uses of this truly precious metal. It is capable of being cast in moulds of any form, of being drawn out into wire of any desired strength or fineness, of being extended into plates or sheets, of being bent in every direction, of being sharpened, hardened or softened at pleasure. Iron accommodates itself to all our wants, our desires, and often our caprices. It is equally serviceable to the arts, to science, to agriculture, and the same ore furnishes the sword, the ploughshare, the spring of a watch or carriage, the chisel, the chain, the anchor, the compass, the cannon, and the bomb. It is a medicine of much virtue and the only metal friendly to the human frame. The ores of iron are scattered over the crust of the globe with a beneficent profusion proportionate to the utility of the metal; they are found under every latitude and every zone, in every mineral formation, and are disseminated in every soil."

The discovery of iron came later than that of gold, silver, or copper, but nevertheless the history of iron goes a long way back. Most historians refer to the fact that Tubal Cain was " an instructer of every artificer in brass and iron " (Gen. iv. 22), and there are many other references to the metal in the Old Testament, proving that iron was well known to the Jews. The classics, too, contain many references to iron, and Scrivener quotes from Homer, Herodotus, Pliny, and others; he also brings together evidence to show that before the Roman invasion the Britons had acquired the art of iron-making and the manufacture of arms, and it is well known that the Romans produced iron during their occupation of these islands from the immense beds of iron cinders which have been discovered in the Forest of Dean and elsewhere, accompanied by coins and other evidences proving them to be relics of the Roman occupation.

There is but little reference to the manufacture of iron between the departure of the Romans and the coming of the Normans, although Camden states that in and before the reign of William the Conqueror the chief trade of the city of Gloucester was forging iron, and it is mentioned in the Domesday Book that there was scarcely any other tribute required from that city by the King than certain " diecars " of iron and iron bars for the use of the Royal Navy.

From the Conquest to the death of John, iron and steel were imported into Britain from Germany and other countries, and the art of making defensive armour was, during this period, brought to a great state of perfection. The records for the year 1290 show that iron was supplied for Westminster Abbey from iron works in Sussex.

Cannon are supposed to have been first used in this country by Edward III. in his invasion of Scotland, and it is well known that the same king had iron cannon with his army at the battle of Crecy and the siege of Calais in 1346.

Until the middle of the eighteenth century the fuel used for the smelting of ore was charcoal, and therefore the chief seats of the iron industry were in the most wooded parts of the country, and particularly in Sussex and Gloucester. Leyland, for instance, speaking of the Forest of Dean, states, " The ground is fruitful of iron ores and divers forges there to make iron "; and Camden, " Sussex is full of iron ores everywhere, for the casting of which there are furnaces up and down the country, and abundance of wood is yearly spent; many streams of

water are drawn into one channel and a great deal of meadow ground is turned into pools for the driving of mills by the flashes, which, beating with hammers upon the iron, fill the neighbourhood night and day with their noise."

Camden also mentions Yorkshire and Staffordshire, remarking with regard to Sheffield that it is "remarkable among many other places hereabouts, for blacksmiths, there being much iron digged up in these parts."

The rise of the iron industry, therefore, had the inevitable effect of denuding the forests of timber, and in 1558 an Act was passed forbidding timber to be felled to make coals for burning iron, but from this Act were specially excluded the county of Sussex, the Weald of Kent, and certain parishes in the Weald of the county of Surrey.

A further Act, passed in 1581, aimed at preventing the destruction of timber, and enacted that no new ironworks should be erected within twenty-two miles of London, within fourteen miles of the River Thames, nor on the Downs or sea-coasts of Sussex, neither should any wood within these limits be converted to "coal" or other fuel for the making of iron. Four years later a subsequent Act prohibited the erection of any new ironworks in Surrey, Kent, or Sussex.

These Acts naturally had the effect of discouraging the manufacture of iron, and of encouraging the import of iron from abroad, and the number of furnaces in the country, which in 1665 had been 300, was reduced by 1740 to 59. That the Acts were not popular with other members of the community besides the ironmasters is clear from a petition to Parliament in 1750 against the Bill for encouraging the importation of iron from our American colonies. The petition was from "the tanners of leather in and about the town of Sheffield in Yorkshire, representing that if the Bill should pass, the English iron would be unsold, consequently a great number of furnaces and forges would be discontinued. In that case the woods used for fuel would stand uncut and the tanners be deprived of oak bark sufficient for the tanneries and support of their occupation." It was, in fact, through the reading of this petition in 1826 that the attention of Scrivenor, one of the earlier historians of the iron and steel industry, was drawn to the trade, for he noticed that the production of iron had increased from about 17,000 tons in 1750 to 600,000 tons in 1826. Production further increased to 1,300,000 tons by 1840, and approximately doubled itself between 1840 and 1850, and since that date the production of pig iron has been quadrupled.

But at the beginning of the eighteenth century the iron industry was a decaying one; for although as early as 1620 Dud Dudley had solved the problem of smelting ore with coal and succeeded in obtaining 3 tons of pig iron from a furnace in one week with coal as fuel, his works were twice destroyed, first by flood and then by riot, and he himself was ruined by his adherence to the Royalist cause, so that his secret died with him.

No further experiments were made until the early part of the next century, when pit coal was first used by Mr. Abraham Darby in his furnaces at Coalbrookdale, but it was still some time before, to quote Scrivenor once again, "the manufacturer found that he possessed in the immense pits of coal an extent of means to which he had until then been a stranger," and "small furnaces, supplied with air from leathern bellows, worked by oxen, horses, or human

labour, were laid aside, and an increase of size took place, together with an increase of the column of blast necessary to produce combustion."

By the middle of the century, however, the ironworks were forsaking the neighbourhood of woods and appearing on the coalfields of the Midlands, South Wales, and Scotland. The following table comparing the number of blast furnaces in 1740 and 1788 illustrates this movement, for it will be seen that, whereas in 1740 there were fifty-nine charcoal furnaces in England and Wales, in 1788 there were only twenty-four, the ten furnaces in Sussex having been reduced to two, the six in Gloucester to four, the six in Yorkshire to one, the six in Shropshire to three, while the four in Kent went out of operation. On the other hand, fifty-nine coke furnaces had been built, twenty-one in Shropshire, nine in Staffordshire, seven in Derbyshire, eight in South Wales, six in Yorkshire, and six in Scotland.

Blast Furnaces in 1740 and 1788.

	1740.	1788.	
	All Charcoal Furnaces.	*Charcoal Furnaces.*	*Coke Furnaces.*
Brecon	2	—	2
Glamorgan	2	3	6
Carmarthen	1	1	—
Merioneth	—	1	—
Cheshire	3	—	1
Denbigh	2	—	—
Derby	4	1	7
Gloucester	6	4	—
Hereford	3	—	—
Hants	1	—	—
Kent	4	—	—
Lancashire	—	3	—
Notts	1	—	—
Salop	6	3	21
Staffs	2	—	9
Worcester	2	—	—
Sussex	10	2	—
Warwick	2	—	—
Yorkshire	6	1	6
Westmorland	—	1	—
Cumberland	—	1	1
England and Wales	59	24	53
Scotland	—	2	6
Total	59	26	59
Production of pig iron	17,350 tons.	14,500 tons.	53,800 tons.
Output per furnace	294 "	560 "	912 "

The introduction of Watts' double power engine between 1788 and 1790 accentuated this movement, and by 1796 the number of furnaces had risen to 121, and the output per furnace had increased to 1,034 tons per annum. By 1802 an additional forty-seven furnaces were either in blast or building, and by

1806 there were 233 furnaces in Great Britain, of which eleven only were charcoal furnaces. The average output of these eleven furnaces was 709 tons per annum, whereas of the remaining 222 coke furnaces, 162 were in blast, giving an annual output of 1,646 tons per furnace. Before leaving the subject of charcoal furnaces it is interesting to note that there is still one charcoal furnace left in this country, at Backbarrow near Lake Windermere. The first smelting furnace built in the North of England was built here in 1712 to replace a finery forge known to have existed since 1623 or earlier. It was rebuilt in 1770, and again a few years ago, when its height was increased to 45 feet. The furnace is usually working three months every year, and was making charcoal iron as recently as December, 1923.

The stimulus given to the industry by Cort's invention of puddling is dealt with in the chapter devoted to wrought iron, while of the reactions of the iron industry and the industrial revolution generally there is no space to deal adequately. Suffice it to say that the invention of the steam engine both largely increased the demand for and provided the means of producing iron and steel in quantities previously undreamed of. Cast iron rails for conveying coal from the mines to the ports or canals were first used in 1767; in 1825 the Stockton and Darlington railway was opened for passenger traffic and for other goods as well as coal, and with the granting of an Act to the Liverpool and Manchester railway the next year the railway era may be said to have begun. Iron barges were first used on the Severn in 1787, and the first seagoing iron vessel sailed from London to Paris in 1820; the first ocean-going steamship of steel was built in 1858. The increasing demand, with its consequent call upon fuel, directed attention to the necessity for improving the construction of the blast furnaces in order to obtain a bigger output per furnace and to the necessity of reducing the quantity of fuel required for smelting. The success which attended the first of these objects is illustrated by the following table:

	Number of Furnaces.			*Production (Tons).*	*Output per Furnace (Tons).*
	Total.	*In.*	*Out.*		
1740	?	59	?	17,350	294
1788	?	85	?	68,300	804
1806	216	161	55	243,851	1,515
1840	490	402	88	1,396,400	3,473
1860	872	582	190	3,889,752	6,683
1880	926	567½	358½	7,749,233	13,655
1900	604	403	201	8,959,691	22,232
1913	496	338	158	10,260,315	30,356
1920	481	284½	196½	8,034,700	28,243
1923	487	200	287	7,438,500	37,192

The much higher output per furnace obtained in 1923 compared with 1920 is due to the fact that on the average only 200 furnaces were in blast during the latter year, and these would naturally be the bigger and more efficient furnaces.

With regard to the reduction in fuel consumption, the invention which effected the greatest saving was that of the hot blast invented by Nielson in 1828. Previous to this discovery over 8 tons of coal were required to produce

1 ton of pig iron. Nielson's invention enabled a ton of pig iron to be produced with but little more than 5 tons of coal, and by 1840, out of 402 furnaces in blast 162 were using hot blast and 240 cold blast, and the average quantity of coal used had fallen to $3\frac{1}{2}$ tons, but varied from 5 tons 9 hundredweights in Yorkshire, where most of the furnaces were still on the cold blast, to 2 tons 16 hundredweights in South Wales. Scrivenor also tells us that in 1831 Mr. Dixon at the Clyde Ironworks substituted raw coal for coke, and by 1833 had succeeded in producing a ton of pig iron with 2 tons 5 hundredweights of coal, excluding the 8 hundredweights required to heat the blast.

In 1869 Mr. Charles Cochrane read a paper before the Institution of Mechanical Engineers in which he pointed out that the actual quantity of coke necessary in a blast furnace was that demanded for the reduction and carburizing of the iron, which he estimated at 17·43 hundredweights per ton of metal (a coal equivalent of about 26 hundredweights), and was optimistic enough to believe that eventually iron would be produced by the consumption of only 13 hundredweights of coke per ton of pig iron. Cochrane, however, modified his opinion the next year and put the minimum amount of fuel required for smelting 1 ton of Cleveland ore at $17\frac{1}{4}$ hundredweights, given a hotter blast and bigger furnace. In 1872, however, Sir Lowthian Bell, in his work on *The Chemical Phenomena of Iron Smelting*, showed that it was impossible to utilize more than a certain fraction of the heat obtained by the combustion of coke in the blast furnace itself, and claimed that the Cleveland ironmasters had already arrived at the minimum coke consumption possible—viz., between 21 and 22 hundredweights per ton of pig iron. This pronouncement had the effect of discouraging further experiments for a time, and the improvement since then has been but slight; but with coal at its present price even small fuel economies are worth making and the experts are, therefore, again working at the problem. In a paper read before the Iron and Steel Institute in 1923 by Messrs. Sutcliffe and Evans, the theoretical minimum consumption of coke per ton of pig iron is put at 8·75 hundredweights, and the opinion was expressed that a figure of 12 hundredweights might be hoped for in actual practice given a suitable type of fuel.

It will have been noticed from the figures given above that the number of blast furnaces now in existence is much less than formerly (the maximum number of furnaces in existence in any one year seems to have been 948 in 1878), but that the output per furnace has steadily increased.

The table on p. 23 shows the number of furnaces in the chief iron-producing districts of the country and their production in 1920.

The average annual output per furnace thus varied from 64,000 tons in South Wales (where some of the modern furnaces are equal to those in America) to 13,300 tons in Scotland. The average annual output per furnace in 1920 in the U.S.A. amounted to over 100,000 tons.

At the present time there are 487 blast furnaces in the United Kingdom, of which 385 are in England and Wales and 102 in Scotland. Of the 385 in England and Wales, ninety are capable of producing over 50,000 tons per annum, of which seven can produce 100,000 tons per annum.

FURNACES AND OUTPUT IN 1920.

Districts	*Total Number of Furnaces.*	*Average Number of Furnaces in Blast.*	*Production of Pig Iron (Tons).*	*Average Output per Furnace per Annum (Tons).*
1. Derby, Leicester, Notts, and Northants	73	45·7	914,400	20,009
2. Parts of Lancs and Yorks,* including Sheffield	37	20·4	591,600	29,000
3. Lincolnshire	22	17·3	589,200	34,156
4. North-East Coast .	114	69·4	2,638,600	38,015
5. Scotland	102	67·9	902,500	13,291
6. Staffordshire, Shropshire, Worcester, and Warwick ..	58	29 5	697,200	23,634
7. South Wales and Monmouthshire	30	10·8	692,000	63,955
8. West Coast	45	23·5	1,009,200	42,944
Total	481	284·5	8,034,700	28,243

* Those parts not included in Districts 4 and 9.

The furnaces belong to ninety-five different works, of which fifteen works produced under 25,000 tons each in 1920, fifty-three between 25,000 and 100,000 tons, and twenty-seven over 100,000 tons; of the last, nine produced over 200,000 tons each.

The location of the blast furnaces in the United Kingdom, as we have seen, has depended upon a variety of considerations, the most important of which has been the reduction to a minimun of transport charges upon materials and products, which are both bulky and heavy. Proximity to coal and ore and access to markets have therefore been the dominating considerations. In the first half of the nineteenth century the furnaces were, in many instances, constructed on coalfields from which ore could also be obtained, or which were adjacent to an orefield. In more recent times the position has been altered by the steady growth of the importation of high-grade foreign ore, which has attracted furnaces to the coalfields adjacent to the coast.

Among the pig-iron producing districts of the country the pre-eminent place is held by the north-east coast. At present this area possesses in a higher degree than any other in the kingdom that combination of advantages which spells success in pig-iron production; and as a result is responsible for approximately one-third of the total production of the country. Cleveland ore and Durham coking coal laid the foundation of this prosperity, and the situation on the coast renders easy the importation of high-grade Spanish ore for the production of hematite pig iron and the despatch of the pig iron to overseas markets or on coasting vessels to other districts in the United Kingdom—*e.g.*, Scotland's deficiency in pig iron is largely made good by coastwise shipping from Middlesbrough. No district can attempt to rival the north-east coast in respect of output, which in 1920 amounted to 2,638,600 tons as compared with 1,009,200 tons produced on the west coast (Cumberland and North Lancs), which ranks second among the pig-iron producing areas. Here, also, the furnaces are on

the Cumberland orefield near the coast, which yields an ore of better quality than that found elsewhere in the kingdom, but the coal has farther to travel than on the opposite coast. The Midlands still form an important centre of production; they possess the necessary coal, but the ore has now to be brought a greater distance than formerly, when it was forthcoming in sufficient quantities on the coalfields themselves, and the inland situation makes the importation of foreign ore practically prohibitive and adds considerably to the cost of exporting the finished product. There is still a good local market for pig iron, but the prospect is hardly so bright as it was when wrought iron and not steel was the chief constructional material, and the Midlands possessed an undoubted supremacy in the iron market. The growing importance of the Midland orefield in Lincolnshire, Northamptonshire, and Leicestershire is causing a shifting of productive capacity eastwards to the coast, and some competent observers consider that Lincolnshire will one day surpass the north-east coast. Ore was first quarried here in 1859 and sent to Sheffield to be smelted; in 1864 the first blast furnace commenced operations, and the first cast of steel was obtained in 1890. In Scotland and in Wales the pig-iron industry, originally based on the native ore near the coalfields, has become, of recent years, more and more dependent upon foreign ore; and even so, both of these districts require to import pig iron to meet the needs of the steel industry.

The first half of the nineteenth century was pre-eminently the age of iron, for although steel had not been entirely neglected, the steel manufactured by the crucible process, which had been developed by Benjamin Huntsman in Sheffield, was too costly for most purposes, and it was not until the invention of Bessemer in 1856 that the production of steel suitable for constructional work at a relatively low price was rendered possible. This was followed by the discovery of the open-hearth process of steel manufacture by the Siemens Brothers between 1864 and 1867. So effective were these improvements that Mr. Jeans quotes a statement from a Thames shipbuilder to the effect that in 1858 the iron ship-plates used in the ships built by his firm cost £40 to £50 per ton. By 1878 the plates produced by the open-hearth process cost £13 to £15 per ton, while within twenty years the plates produced by the same process were selling as low as £5 to £6 per ton, a price, however, due to special and uneconomic circumstances and one unlikely to be reached again. The significance of this change is at once apparent when it is remembered that on the average 1 ton of iron and steel is required for every 2·1 tons of gross shipping tonnage.

In 1877 Mr. Sidney Gilchrist Thomas, who was then a clerk in the Thames Police Court, conceived the idea of rendering the Bessemer and Siemens processes capable of removing phosphorus, and this process was developed by himself, his cousin Gilchrist, and others between 1879 and 1883. This had the effect not only of making available for steel manufacture the large deposits of phosphoric ore in this country, but of enabling the minette deposits in Lorraine and Luxemburg to be developed and also the phosphoric ores of America. Railways soon joined Lorraine ore to Westphalian coal and Lake Superior ores to Pittsburg coal, and the increase in the world's production was so great as temporarily to outstrip the demand. The price for steel rails fell from

£12 1s. 1d. per ton in 1874 to £5 6s. in 1883, iron rails from £9 18s. 2d. to £5 per ton,* and Cleveland pig iron from £4 17s. 1d. in 1872 to £1 12s. 10d. in 1875.

The greatest advances since the discovery of the Thomas-Gilchrist process have been the introduction of metal mixers, whereby the use of liquid metal direct from the blast furnaces in the steel works is facilitated; the invention of the Talbot process; the increase in number of electric furnaces; the increase in the production of alloy steels, the introduction of various mechanical appliances, and the attention paid to the recovery of by-products both from blast and steel furnaces. With regard to metal mixers, Sir W. Siemens had built his open-hearth furnaces at Landore near the blast furnaces, hoping to use fluid metal instead of cold pig iron, but the first manufacturer in this country actually to use liquid metal to make direct into steel was Colonel Sir John Roper Wright, now chairman of Baldwins, Ltd. The first mixer to be used in England was at Barrow in 1889, and had a capacity for 150 tons; a second mixer of 250 tons was erected at Barrow in 1901, and with the beginning of the twentieth century metal mixers came into practically general use. In 1903 Mr. (now Sir) Frederick Mills built a 750 tons gas-fired mixer at Ebbw Vale, but the majority of mixers now have a capacity of about 400 tons. It should be added that a mixer is practically a very large steel-melting furnace, which is used not only for storing metal for use in the basic open-hearth furnaces, but an "active" mixer serves as a refiner as well. The advantages derived from the use of the mixer are (1) economy of fuel, (2) simplification of charging of the open hearth, and (3) reduction of costs by purification of pig iron, which results in quicker working and decreased consumption of limestone and iron ore in the steel furnaces.†

Whereas the majority of the open-hearth furnaces in this country have a capacity of 50 to 60 tons, the Talbot furnaces, invented by Mr. Benjamin Talbot, are mostly between 175 and 200 tons capacity, and the weight of steel tapped from the furnace every six hours is about 55 to 60 tons, so that the weekly average output is about 1,000 to 1,200 tons. Mr. Talbot contemplates that eventually furnaces of 500 tons will be installed.

Before the War only a few electric furnaces were used in connection with the iron and steel industry in Great Britain, but soon after 1914 a number of melting furnaces, mainly of the Heroult type, were erected in Sheffield and other parts of the country, to deal with the enormous quantities of shell borings produced. The following is from Dr. Stead's presidential address to the Iron and Steel Institute in May, 1920, and is based on information supplied to him by Messrs. Campbell, Gifford, and Waite:

"The electric steel furnace, which, up to the outbreak of War, only produced a very small proportion even of the higher grades of steel, has developed with great rapidity during the last few years. Before the War progress had been most rapid in Germany, where conditions were peculiarly suitable to its use. Most of the German electric steel was made by refining basic Bessemer steel, and furnaces

* Sir Lowthian Bell, Second Report Depression of Trade Commission, quoted by L. C. A. Knowles, *Industrial and Commercial Revolutions in Great Britain during the Nineteenth Century*.

† Colclough, in the *Chemical Age* for March 1, 1924.

up to 30 tons capacity have been installed for this purpose. The United States came second, and Italy, America, and France were all ahead of England in production. During the War great progress was made here, and the production is now only surpassed by the United States and Germany. The latter still holds second place, but only because most of the steel there is refined basic Bessemer steel, while the British furnaces are in practically all cases melting cold scrap.

"The product in England, before the War, was probably about 10,000 tons a year, though no exact figures are available. This was made in eleven furnaces with a total transformer capacity of about 4,500 kilowatts. The possible production at the present day, if all furnaces were worked to their full capacity, is about 300,000 tons a year. In 1918 a number of furnaces had either just started work or were not completed, and several were shut down immediately after the Armistice was signed.

"In 1918 about 40,000 tons of the steel produced was required for the manufacture of castings. The problem of finding an immediate market for the steel from the furnaces making ingots, of which over 100,000 tons were produced in 1918, was a difficult one. During the War they were principally making steel for bullet-proof plates, aeroplanes, motor-cars, armour-piercing shell, and steel helmets, and the orders for all this material were, of course, cancelled."

In 1919 the output of electric steel was 89,100 tons, but in 1922 only 39,400 tons.

To summarize the history of steel manufacture in figures we give below the output of steel at different dates from 1873 to 1923.

1873	573,301 tons.
1880	1,294,933 ,,
1890	3,579,063 ,,
1900	4,901,060 ,,
1910	6,374,481 ,,
1913	7,663,900 ,,
1917 (year of maximum production)	9,716,544 ,,
1920	9,067,300 ,,
1923	8,488,900 ,,

In 1873 the production of open-hearth steel amounted to 77,473 tons; in 1917 the production was 7,900,767 tons. Ingot steel is manufactured in ninety-two different works in the country, of which twenty-eight produced under 25,000 tons in 1920, and twelve over 200,000 tons. The number of works manipulating steel is, of course, very much larger. The following table shows the chief steel-producing districts in 1920:

Scotland	2,074,000 tons
North-East Coast	1,950,000 ,,
South Wales and Monmouthshire	1,884,300 ,,
Sheffield	980,200 ,,
Staffs, Shropshire, Worcester, and Warwick	806,200 ,,
Remainder of United Kingdom	1,372,600 ,,
Total	9,067,300 ,,

Foreign Trade.

The iron and steel industry is essentially an export one; in 1913 about five million tons of iron and steel were exported, about a quarter of which was in the form of pig iron. During the War nearly all the iron and steel produced was required for munitions in one form or another, so that exports, except to Allies, had to be rigorously cut down, as will be seen from the following figures:

	To Allies (Tons).	To Other Countries (Tons).	Total, including Scrap (Tons).
1913	1,096,998	3,952,092	5,049,090
1915	1,274,950	1,973,096	3,248,046
1918	1,197,741	421,257	1,618,998

To get back our pre-war export trade and to increase it, is one of the big problems now facing the industry, for one result of the War was to increase the steel capacity of the country by about 50 per cent. In 1923, however, exports amounted only to 87 per cent. of those in 1913. A comparison of the chief exports in 1913 and 1923 is given below:

	1913 (Tons).	1923 (Tons).
Pig iron and ferro alloys	1,124,181	894,298
Iron and steel bars, rods, angles, sections, etc.	392,511	380,581
Plates and sheets, including black plates and sheets	273,876	529,450
Galvanized sheets	762,075	602,360
Tinned plates and tinned sheets	494,497	551,127
Tubes, pipes, and fittings (cast and wrought)	399,608	242,200
Steel rails	506,585	307,049
All other items	1,015,891	812,506
Total	4,969,224	4,319,571

Nearly half our exports of iron and steel before the War were to British Possessions, the other half being almost equally divided between European and non-European foreign countries. India, Australia, and South Africa took the bulk of our exports to British Possessions; France, Germany, Italy, Belgium, and Sweden were our chief customers in Europe, while the Argentine, Japan, Brazil, and the U.S.A. were our best markets outside of Europe.

The two following tables analyse the export and import trade in iron and steel in 1923:

UNITED KINGDOM: EXPORTS OF IRON AND STEEL

Country of Destination.	Pig Iron: Forge and Foundry	Pig Iron: Acid and Basic.	Iron Bars Rods, Angles, etc.	Steel Bars, Rods, Angles, etc.	Girders, Beams, Joists, and Pillars.	Hoops, Baling, and Barrel	Hoops and Strips for Tubes.	Steel Plates and Sheets not under ⅛ Inch Thick.
1. Finland	6,062	1,840	14	3,820	12	217	10	338
2. Poland	3,595	1,870	—	1,057	—	3	8	1,724
3. Norway	7,142	2,093	140	4,380	17	365	57	3,050
4. Sweden	26,993	3,835	31	3,136	16	264	82	3,057
5. Denmark	18,844	9,527	167	7,354	118	1,363	10	9,222
6. Germany	63,852	79,806	309	26,207	196	1,815	30	23,073
7. Netherlands	16,243	6,218	324	9,512	77	781	213	6,865
8. Belgium	31,107	58,292	78	3,858	71	163	115	286
9. France	16,597	39,495	50	6,367	26	421	785	1,049
10. Switzerland	1,784	3,555	29	348	—	2	9	4
11. Portugal	2,688	63	231	2,416	142	591	7	642
12. Spain	1,449	215	133	6,657	395	569	211	3,991
13. Italy	29,118	35,872	7	768	45	1	23	318
14. Rumania	60	—	200	435	—	67	—	—
15. Greece	235	20	13	257	17	60	—	160
16. Java	1,575	58	15	984	7	260	15	663
17. Siam	895	—	36	1,949	86	29	—	570
18. China	780	—	289	8,097	366	3,931	103	2,830
19. Japan	5,568	1,550	1,227	20,700	5,531	2,996	692	8,519
20. Portuguese East Africa ..	125	—	457	4,292	234	104	—	1,577
21. Chili	1,283	50	700	1,945	526	595	—	1,486
22. Brazil	1,267	305	1,386	3,432	31	1,378	45	1,004
23. Argentine	2,154	—	556	4,990	190	1,511	6	1,703
24. Other South America ..	946	25	784	1,253	204	291	6	531
25. United States	168,158	16,082	130	4,416	80	3,647	669	227
26. Other foreign countries ..	4,019	967	671	7,660	676	1,204	12	1,248
27. Total foreign countries ..	412,539	261,738	7,977	136,290	8,863	22,628	3,117	74,137
28. India and Ceylon	9,012	100	4,109	48,131	22,964	23,664	315	52,285
29. Straits Settlements	1,635	238	347	6,436	1,186	337	45	3,701
30. Hong Kong	1,080	—	377	5,021	1,709	126	—	5,809
31. Egypt and Palestine	1,361	165	231	4,100	1,949	9,048	22	1,332
32. British East Africa	281	—	216	887	296	212	—	264
33. British West Africa	232	20	886	1,803	394	271	—	513
34. South Africa	2,081	1,091	3,842	11,299	3,278	869	23	7,339
35. Canada	12,208	350	2,655	16,322	1,309	829	614	9,846
36. Australia	7,567	955	8,450	83,421	26,215	5,320	169	31,722
37. New Zealand	5,489	155	8,385	17,788	4,041	2,312	20	3,942
38. British West Indies	69	—	433	471	1,199	442	—	303
39. Other British possessions ..	6,083	130	5,543	5,161	3,390	1,331	25	1,255
40. Total British possessions ..	47,098	3,204	35,474	200,840	67,930	44,761	1,233	118,311
41. Unallocated	—	—	—	—	—	—	—	—
Total .. { Tons	459,637	264,942	43,451	337,130	76,793	67,389	4,350	192,448
Total .. { Value (£)	2,517,870	1,447,140	600,223	4,449,370	814,016	947,435	96,606	2,176,029

ANALYSED BY PRODUCT AND COUNTRY, 1923 (TONS.)

	Steel Black Sheets under 1/8 Inch Thick.	Steel Black Plates, including Canada Plates.	Iron and Steel Rails (Railway).	Steel Rails grooved for Trams.	Sleepers and Fish-Plates.	Tubes, Pipes, and Fittings (Cast and Wrought).	Galvanized Sheets.	Tinned Plates and Sheets.	Wire and Wire Manufactures	Other Manufactures for which Details are partly given.	Total.
1.	1,982	153	29	—	—	—	3,518	1,503	—	—	19,498
2.	413	1,145	—	—	—	—	526	1,060	—	—	11,401
3	1,427	82	35	—	—	—	5,299	19,114	—	711	43,912
4.	5,385	1,913	658	323	43	—	5,029	7,595	—	—	58,360
5.	1,049	751	5	—	—	—	6,638	14,159	—	—	69,213
6.	9,926	14,625	24,235	—	445	—	1,921	22,782	929	404	270,555
7.	2,163	4,843	35	104	8	—	2,556	36,239	—	1,832	88,013
8.	3,298	6,332	664	—	3	—	1,924	22,568	—	21,456	150,215
9.	12,106	7,587	41	447	47	—	343	38,003	—	—	123,364
10.	157	61	—	—	—	—	76	3,433	—	—	9,458
11	1,160	130	2,012	—	1,257	—	1,688	19,248	—	—	32,275
12.	1,391	1,364	1,516	176	120	—	3,002	16,520	—	—	37,712
13.	767	272	—	15	—	—	320	19,029	—	—	86,555
14.	1,220	1,013	—	—	—	—	1,092	5,270	—	—	9,357
15.	174	28	10	—	—	—	1,777	1,999	—	—	4,750
16.	82	—	2	—	—	—	7,639	—	—	—	11,300
17.	91	—	352	—	9	—	2,580	402	—	—	6,999
18.	5,549	46	362	840	53	—	14,509	29,554	—	—	67,309
19.	175,573	3,702	31	17	—	2,779	19,323	37,658	—	—	285,666
20.	75	—	2,208	2,201	529	—	5,541	9	—	—	17,352
21.	4,798	344	1,411	205	95	—	6,970	3,161	—	—	23,569
22.	1,888	811	843	296	167	—	8,571	17,161	3,168	—	41,753
23.	1,858	374	5,718	52	1,305	15,737	84,418	27,023	5,490	3,177	156,262
24.	355	28	6,574	111	279	—	10,219	2,785	222	—	24,613
25.	874	112	286	—	6	—	—	9,680	2,656	106,668	313,691
26.	4,296	175	24,583	49	9,914	—	34,907	44,227	—	—	133,798
27.	238,057	45,891	71,610	4,836	14,280	18,516	229,576	400,182	12,465	134,248	2,096,950
28	15,621	650	85,487	1,929	24,865	47,792	154,033	58,908	10,388	91,482	651,735
29	469	4	953	—	34	4,068	9,666	—	—	6,593	35,712
30.	813	—	97	—	3	—	1,705	–	—	—	16,740
31.	499	10	22,558	6	10,561	—	2,251	8,829	—	1,562	64,484
32.	109	76	5,788	—	6,226	—	3,234	278	—	—	17,867
33.	127	16	21,909	3	21,482	—	12,629	151	—	—	60,436
34.	1,922	150	30,777	629	2,087	23,497	34,828	5,494	15,527	32,191	176,923
35.	5,103	5,839	132	—	—	—	7,336	27,319	7,957	1,260	99,079
36.	17,244	406	27,635	9,458	1,788	43,894	112,197	42,369	31,582	20,624	471,016
37.	2,204	120	16,332	1,503	731	7,994	21,721	5,110	12,988	5,372	116,207
38.	28	9	520	25	61	—	—	280	—	—	3,840
39.	729	906	3,870	992	190	2,531	13,184	2,207	878	2,404	50,809
40.	44,868	8,186	216,058	14,545	68,028	129,776	372,784	150,945	79,320	161,487	1,764,848
41.	—	—	—	—	—	93,908	—	—	39,383	324,482	457,773
	282,925	54,077	287,668	19,381	82,308	242,200	602,360	551,127	131,168	620,217	4,319,571
	4,922,220	971,904	2,562,215	308,418	950,251	5,707,631	12,567,395	12,601,409	4,639,163	13,218,773	76,201,990

UNITED KINGDOM: IMPORTS OF IRON AND STEEL ANALYSED BY PRODUCT AND COUNTRY OF CONSIGNMENT IN 1923 (TONS).

	Sweden.	*Netherlands.*	*Belgium.*	*Germany.*	*France.*	*Luxemburg.*	*U.S.A.*	*Other Countries.*	*Total.*
Pig iron:									
Forge and foundry ..	14,743	—	18,900	—	7,403	3,775	7,194	270	52,285
Basic	—	505	24,628	3,400	8,856	1,470	—	—	38,859
Iron and steel blooms, billets, and slabs	7,098	1,221	205,302	20,130	162,033	30,898	207	1,291	428,180
Iron bars, rods, angles, etc.	9,999	2,588	120,898	4,832	1,671	2,520	—	416	142,924
Steel sheet bars	—	6,007	76,789	1,194	23,520	20,349	244	85	128,188
Tin-plate bars	—	7	10,210	—	4,996	606	6	—	15,825
Wire rods	4,389	2,668	24,434	6,994	6,572	218	371	3,641	49,287
Other steel bars, rods, and angles	1,580	1,529	44,603	12,422	3,728	3,030	15,746	1,611	84,249
Girders, beams, joists, etc.	—	279	38,209	165	9,855	12,800	—	130	61,438
Hoops, baling, and barrel ..	—	48	202	726	—	36	124	28	1,164
Hoops and strips for tubes	116	252	2,743	820	373	10	9,866	14	14,194
Steel sheets and plates not under $\frac{1}{8}$ inch	2	1,275	20,302	43,144	1,189	279	140	305	66,636
Black plates, including Canada plates	17	—	4,425	777	289	21	13	—	5,542
Black sheets under $\frac{1}{8}$ inch ..	29	322	3,932	71	78	6	353	8	4,799
Steel rails grooved for trams	—	—	1,560	—	477	—	—	—	2,037
Steel rails (railway) ..	—	662	4,500	364	3,376	12	6	8	8,928
Iron castings (in the rough)	12	16	719	61	29	—	36	180	1,053
Steel castings (in the rough)	90	27	4,311	306	10	—	155	266	5,165
Total .. Tons	38,075	17,406	606,667	95,406	234,455	76,030	34,461	8,253	1,322,627*
Total .. Value (£)	549,754	147,671	4,707,270	663,786	1,619,353	554,009	480,869	135,357	13,782,218

* Includes 211,874 tons, comprising tubes, pipes, and fittings (cast and wrought), wire and wire manufactures, and other small items not specified.

Labour.

According to the latest issue of the *Ministry of Labour Gazette* (February, 1924), the following are the numbers employed in the different sections of the iron and steel industry:

Estimated Number of Insured Persons at July, 1923 (Great Britain and Northern Ireland).

	Males.	*Females.*	*Total.*
Pig iron manufacture (blast furnaces)	29,310	240	29,550
Melting furnaces, iron and steel-rolling mills ..	210,150	4,480	214,630
Manufacture of tin-plates	25,860	4,330	30,190
Iron and steel tube making	23,900	1,450	25,350

while the industries providing the raw material or using steel as their principal raw material, such as engineering, electrical engineering, marine engineering, motor vehicle and aircraft manufacture, railway carriage, wagon and tramcar building, etc., account for an additional 1,700,000. Mr. W. T. Layton, now editor of the *Economist* and a former director of the National Federation of Iron and Steel Manufacturers, in a lecture to officials of the Ministry of Labour in November, 1921, on the relations of capital and labour in the iron and steel industry, said:

"The industry is the field of a very old established network of machinery of conciliation boards which have had the effect of producing the good relations between employers and work-people which have existed for a long time. Stoppages have, unfortunately, been rather frequent of late, but they are almost always caused by disputes external to the industry—*e.g.*, by the coal miners, bricklayers, engineers, etc. Among iron and steel workers proper the system of conciliation and of sliding scales has, broadly speaking, prevented any substantial dispute since it began some fifty years ago.

"The conciliation machinery varies in detail all over the country, but the governing feature of it is the sliding scale, which is based upon the average selling price of the product, so that in some form or another wages vary in accordance with the variation in the ascertained price of the product. The theoretical justification for the system lies in the assumption that its variations are due to variations in demand, or in the state of trade, and that the price of the product is an index of the prosperity of the trade and an indication of profits and of the ability to pay wages.

"When this scheme was first introduced it was held as being of the very greatest economic importance, and was loudly acclaimed by distinguished economists. The particular advantages claimed for it were five: (1) That it was an automatic means of determining disputes about wages; (2) that it tended to promote co-partnership and common interests between employers and employed, in that to some extent it is based on a profit-sharing idea; (3) that it enabled employers to calculate their costs of production with greater accuracy because it eliminated the probability of disputes about wages, over definite periods; (4) that it allowed wages to vary by small stages, and (5) that it made possible prompt

losses, the Belgian manufacturers see in it merely an aggravation of their difficulties through an intensification of competition. At the moment, with the existing lack of organization among producers, this view may be correct, but in the long run, there is little doubt that an organization of producers on the lines to which the German *Kartell* system has accustomed the Luxemburg works will lead to a considerable augmentation of Belgian economic strength. On the basis of the 1913 figures we must credit the new union with an annual production of 5 million tons of pig iron and of 3·7 million tons of steel.

CHAPTER II

THE RAW MATERIALS OF THE BRITISH IRON AND STEEL INDUSTRY

THE chief raw materials of the iron and steel industry are obviously iron ore and coal or coke, and since it requires 2 to 3 tons of ore, according to quality, and up to 2 tons of coal, to produce 1 ton of pig iron, it follows that a successful iron and steel industry can only exist where there are ample supplies of at least one or other of these commodities. The United States is the only big iron and steel producing country which does not require to supplement its own resources either in ore or coal, and even here many hundreds of miles separate Lake Superior ore and Pennsylvania coal, but these difficulties of distance have been overcome by exceptionally well-organized means of transportation. Great Britain has ample supplies of coal, and also of iron ore, but much of Great Britain's iron ore is of a low grade, and therefore has to be supplemented by imports of higher grade ore from Spain, Sweden, and elsewhere. Both Germany and Belgium require to import ore, while France, on the other hand, has to import fuel, either as coal or coke. Great Britain is the only steel-producing country with suitable coal supplies near the coast to which foreign ore can be brought by sea and the product re-shipped.

In the early days of the industry, when the furnaces were small and the processes available crude, the iron content of the ore was the most important consideration, but when ores containing as little as 20 per cent. of iron can, under favourable circumstances, be smelted, it is clear that the iron content, though obviously important, is not the predominant consideration. Other considerations are the mass of ore available, the cost of transporting ore to fuel or fuel to ore, the cost of winning the ore—which depends partly on the cost of labour and partly on the situation of the ore and hardness of the rock—the cost of the "flux," the percentage of harmful material present, the mechanical condition of the ore, etc.

Before the War iron ore was being consumed at the rate of 170,000,000 tons per annum, and as the quantity of high-grade ore gradually decreases, it becomes necessary to mine and transport ores of inferior quality. The practice known as

" beneficiation " has, therefore, arisen, whereby the amount of useless matter to be transported (such as water, silica, etc.) is reduced and the percentage of iron increased. The most important methods of beneficiation in use are: (1) Heating to drive off volatile matter—*e.g.*, the carbonate ores of Great Britain are calcined either in open heaps or in kilns to drive off water and carbon dioxide, which reduces the weight of the ore sometimes by as much as one-fourth; (2) washing and mechanical concentration, which is used in some parts of the United States and Sweden to eliminate siliceous and argillaceous impurities; and (3) magnetic concentration, which is also practised both in the United States and Sweden.

The year 1913 was the year of maximum production of iron ore and seems likely to remain so for some time to come. We therefore give below the twelve countries which in that year produced upwards of 1,000,000 tons, together with the import and export figures for that year where available. The figures for Germany and France are for those countries as constituted in 1913, but it must be remembered that, as the result of the War, Alsace-Lorraine, which in 1913 produced 21,136,300 tons of iron ore, was transferred from Germany to France.

IRON ORE—PRODUCTION, IMPORTS AND EXPORTS IN 1913 (IN THOUSANDS OF TONS).

	Production	*Imports.*	*Exports.*
United States	59,643	2,595	1,042
Germany and Luxemburg .. .	35,364	13,794	2,571
France	21,566	1,388	9,905
United Kingdom	15,997	7,441	5
Spain	9,703	—	8,676
Russia	7,947	?	?
Sweden	7,355	3	6,336
Austria-Hungary	5,016	927	104
Cuba	1,582	—	1,582
Algeria	1,327	—	1,343
Newfoundland	1,243	—	1,243
Total (including other countries) ..	170,149	26,148	32,807

It will be seen that the four largest consumers of iron ore are also the biggest producers, that Spain and Sweden exported nine-tenths of their production, and that Cuba, Algeria, and Newfoundland exported the whole of their production. The iron industry of Belgium is based on imported ore, and imports in 1913 amounted to 6,971,000 tons compared with a home production of only 148,000 tons.

The predominance of the United States is most marked, and this predominance has since increased, for in 1920 America raised 68,372,000 tons of ore out of a world production of 122,000,000—that is, the rest of the world, which in 1913 produced 110,636,000 tons, produced in 1920 only 54,000,000 tons, and in 1922, 47,128,500 tons. A very valuable survey of the present and prospective iron ore supplies of the world was recently undertaken by the Imperial Mineral Resources Bureau, and the results published in eight volumes, and it is from the Reports

of this Bureau that much of the information with regard to iron ore in this and the succeeding chapter has been obtained.

The following table, dealing with the United Kingdom, summarizes the ore resources as follows:

IRON ORE RESOURCES: GREAT BRITAIN (IN MILLIONS OF TONS).

	Total Reserves (1920).	*Actual Reserves.*	*Probable Reserves.*	*Possible Reserves*	*Ores raised* (1917, 1918, *and* 1919)
Jurassic ores	3,773·7	1,212·0	2,177·00	420·00	35·30
Carboniferous bedded ores ..	7,716·3	1,049·5	1,247·09	5,423·23	3·55
Hematites	130·3	45·0	90·00	—	4·70
Other deposits	90·7	—	15·55	75·50	0·31
Total	11,711·0	2,306·5	3,529·64	5,918·73	43·86

1. *The Jurassic Ores.*—It will be seen that 80 per cent. of the ore now being worked comes from the jurassic beds, where the actually developed resources amount to over 1,200 million tons, equivalent to 100 years' working, and that the probable total quantity available is something like three times as much. Out of the total reserves of 3,774 million tons, 428 million tons are in the Cleveland district of Yorkshire, 490 million tons in the Frodingham district of North Lincolnshire, and 2,245 million tons in the Northampton bed of Northants, Rutland, and South Lincolnshire. The analysis of the raw stone dried at 212° F. is thus given in the report just referred to:

	Fe.	*Mn.*	*SiO_2.*	*Al_2O_3.*	*CaO.*	*MgO*	*S.*	*P.*
Northamptonshire and Rutlandshire (inferior oolite)	38·2	0·28	17·4	7·2	3·1	0·5	0·12	0·71
Cleveland, Yorkshire (middle lias)	30·2	0·44	12·7	11·0	5·1	3·8	0·28	0·51
Leicestershire and South Lincolnshire (middle lias)	30·2	0·27	13·0	9·6	11·4	0·7	0·13	0·30
Oxfordshire (middle lias)	28·3	0·32	12·0	8·9	14·4	0·7	0·07	0·27
North Lincolnshire (lower lias) ..	25·4	1·07	9·1	5·7	20·3	1·1	0·18	0·35

The reserves of jurassic ore were of great importance during the War, when the submarine campaign curtailed supplies of Spanish ores, although the use of this phosphoric ore involved extensive alterations to much of the blast furnace and steel plant of the country, which was designed for acid pig iron and steel. Although relatively poor in iron, the jurassic ores are of great economic importance, since they are of considerable thickness and extent. Moreover, except in the Cleveland district, where the workings are now exclusively underground, the ironstone is, for the most part, quarried at the surface after a layer of sand, soil, or clay has been removed. This enables very economical working, for whereas the average output per man per shift is little more than 2 tons in underground workings, it is 4 or 5 tons per man per shift in the open workings, and as much as 15 tons where mechanical excavators can be used. From returns made to the Ministry of Munitions in 1917, it was found that 27 per cent. of the ore raised

in South Lincolnshire, Rutland, Northampton, Leicester, and Oxford was consumed locally; most of the remainder went to blast furnaces in the coalfields, particularly the Derbyshire and Nottingham coalfield, and the balance was almost equally divided between the furnaces of Cleveland and North Lincolnshire for mixing purposes.

Records of the output of the Cleveland ironstone mines exist for each year from 1860 to date, and the following table gives the annual output at the end of each decade:

1860	1,471,319 tons.
1870	4,072,888 ,,
1880	6,486,654 ,,
1890	5,617,573 ,,
1900	5,493,733 ,,
1910	6,152,823 ,,
1920	3,717,880 ,,

2. *Carboniferous Ores.*—Formerly the carboniferous ores furnished the bulk of the raw material used in this country, but the thicker and more profitable seams are now more or less exhausted, and the reserves now occur mostly as nodules or in thin bands. The output, which in 1855 amounted to 7,848,600 tons, had, therefore, fallen by 1918 to 1,122,800 tons, and in 1922 to 273,152 tons. At present it is only possible to mine the ironstones apart from their associated coals in North Staffordshire, where the beds of ironstone range from 1 foot to 6 feet in thickness. The ironstones of the coal measures are still abundant and fairly rich in iron content, but because of the thinness of the individual beds and the amount of waste left in working them, the irregularity in the occurrence of any particular bed, the compact nature of the strata, and the adherence of foreign deleterious substances which must be removed mechanically or by weather, the extraction of the iron is not profitable. Coal measure ironstone is smelted chiefly in Staffordshire and Shropshire; in Yorkshire the smelting of coal measure ores is confined to the Low Moor district, and in the Sheffield, Derbyshire, Nottingham and South Wales districts the ores have practically ceased to be used at all. Warwickshire sends some ironstone to South Staffordshire, but does not now smelt any locally, while the output of the remaining coalfields is negligible. In Scotland the output has fallen from 2½ million tons in 1876 to about 350,000 tons in 1918, and to 86,530 tons in 1922, which was, however, an exceptionally poor year.

3. *Hematites of Cumberland and Lancashire.*—The importance of the hematite ores of Cumberland and Lancashire lies in the fact that they are the only native ores low in phosphorus and sulphur. They therefore furnish pig iron very suitable for the acid process and yield an exceptionally pure steel. When the War broke out, and difficulty in obtaining sufficient hematite from Spain was experienced, many mines that had been abandoned in Cumberland and Lancashire were re-opened. They are also the richest ores in iron content in the country. The mean of analyses of ore from eleven different sources in Furness in November, 1917, received by the Barrow Hematite Steel Company, of Barrow, are given in the Bureau's Report as follows:

	Iron.	Insoluble Residue.	$CaCO_3$.	P.	Moisture.
1	48·42	17·27	6·34	0·014	6·96
2	49·12	16·67	5·73	0·012	7·17

1=mean of eleven analyses of ore from eleven different sources in Furness in November, 1917.
2=weighted mean analysis of the same; dry sample.

The actual reserves of hematite ores amount to about 45,000,000 tons, sufficient, at a rate of consumption of $1\frac{1}{2}$ million tons per annum, for about thirty years. There are, however, probably reserves sufficient to prolong the life of the mines for a further period of sixty years. Before the War output was in the neighbourhood of 1,800,000 tons per annum, but in 1920 the output was only 1,257,000 tons, and in 1922 only 839,801 tons.

4. *Other Deposits.*—The deposits of iron ore other than jurassic, carboniferous, and hematite occur in many areas, but nowhere in sufficient quantity for economic working. The ore raised from these other deposits amounted in 1917, 1918, and 1919 to no more than an average of 100,000 tons per annum.

It will be seen that there are very considerable reserves of iron ore in this country, but that except in Cumberland and Lancashire it is relatively poor in iron content. For this reason approximately one-half of the pig iron made is from richer imported ore which is smelted in furnaces situated at or near the seaboard adjacent to the coalfields. In spite of the efforts made during the War to develop home ores, the proportion of ores imported is now higher than before the War, on account of the high cost of railway transport and fuel.

The total output of home iron ore from 1910 to 1922 was as follows:

1910	15,226,015 tons.	1917	14,845,734 tons.
1911	15,519,424 ,,	1918	14,613,032 ,,
1912	13,790,391 ,,	1919	12,254,195 ,,
1913	15,997,328 ,,	1920	12,706,895 ,,
1914	14,867,582 ,,	1921	3,477,955 ,,
1915	14,235,012 ,,	1922	6,867,512 ,,
1916	13,494,658 ,,		

Further particulars with regard to the output of iron ore can be obtained from the publications of the Mines Department of the Board of Trade, who issue an Annual Report, and also quarterly figures showing the production of ore in the different districts, the average percentage of iron in the ore, its selling value at the mines, and the numbers of men employed.

It is from the Annual Report of the Chief Inspector of Mines for 1922 that the table on p. 39 has been compiled.

Imported Ores.

It was the invention of the Bessemer process in 1856 which first rendered necessary the import of iron ore on a considerable scale, for this process demanded an iron free from phosphorus, and, as we have seen, this conditions was only met by the iron ores of Cumberland and Lancashire. The proximity of the coal-

PRODUCTION OF IRON ORE AND IRONSTONE BY KINDS AND DISTRICTS, 1913, 1920, AND 1922.

Kind of Ore.	Principal Districts of Production.	1913.	1920.	1922. Total Output of Raw Iron Ore and Ironstone.	1922. Average Percentage of Iron in the Clean Raw Material.	1922. Total Net Selling Value at the Mine or Quarry.	1922. Average Net Selling Price per Ton at the Mine or Quarry.	1922. Average Number of Persons Employed.
		Tons.	*Tons.*	*Tons.*	*Per Cent.*	£	s. d.	
West Coast Hematite (non-phosphoric)	Cumberland	1,767,088	1,257,388	625,935	52	693,318	22 2	3,166
	Lancashire			213,866	51	229,614	21 6	889
Total ..	.. ..	1,767,088	1,257,388	839,801	51	922,932	22 0	4,055
Jurassic ironstones:								
(*a*) Lower lias ironstone	N. Lincolnshire (Frodingham)	12,572,268	10,413,705	1,363,575	22	188,863	2 9	486
(*b*) Middle lias ironstone	Cleveland (N. Yorkshire)			1,169,754	29	498,166	8 6	2,981
(*c*) Middle lias ironstone	S. Lincolnshire, Leicester, Northampton, Oxford			906,432	25	140,498	3 1	756
(*d*) Inferior oölite ironstone	S. Lincolnshire, Northampton, Rutland			2,210,065	33	397,328	3 7	2,073
Total ..	.. ..	12,572,268	10,413,705	5,649,826	28	1,224,855	4 4	6,296
Coal measure ironstone (blackband and clay ironstone)	N. Staffordshire	1,542,053	950,004	151,951	30	95,633	12 7	772
	S. Staffordshire			16,595	30	11,090	13 4	71
	Scotland			86,530	30	51,906	12 0	482
	Other coalfields			18,076	33	11,516	12 9	138
Total ..	.. ..	1,542,053	950,004	273,152	30	170,145	12 5	1,463
Other occurrences of iron ore	Devonshire, Forest of Dean, Somerset, Weardale, Wiltshire, Carnarvon, Flint, Glamorgan, Isle of Man	115,919	85,798	104,733	—	76,089	—	265
Total, United Kingdom ..		15,997,328	12,706,895	6,867,512	31	2,394,021	7 0	12,079

fields to the sea on the North-East Coast, the West of Scotland, and South Wales facilitated this import, and in 1860 imports from Spain amounted to 20,542 tons, in 1870 to 179,083 tons, and by 1880 to 2,778,962 tons.

Spain is still the principal overseas supplier of iron ore, sending five or six times as much annually as Algeria, from which we import the next largest quantities. The other chief sources of supply are Sweden, Tunis, Norway, and France; imports from Greece have dwindled very much in the last few years. While, as we shall see in a subsequent chapter, the British Dominions possess vast resources of iron ore, most of them are too far away to bear the present high transport costs, the only British Possession from which substantial supplies have hitherto been drawn being Newfoundland, from which 100,000 tons was received in 1913:

We select analyses of Best Rubio, Djerissa, and Hamed from the analyses of imported ores given in Part I. of the Report of the Imperial Mineral Resources Bureau.

	Kind of Ore.		
	Best Rubio, Bilbao (per Cent.).	*Djerissa, Tunis (per Cent.).*	*Hamed, Algeria (per Cent.).*
Total iron	47·06	52·07	45·50
Ferric oxide	67·23	74·38	65·00
Sulphur	0·040	0·034	0·053
Manganese oxide	1·42	2·73	1·65
Phosphoric acid	0·047	0·030	0·072
Silica	10·30	1·23	4·39
Moisture	9·58	5·62	8·49

The following table gives the quantities of iron ore imported into the United Kingdom in the two years before the War and in 1920 and 1922:

IMPORTS OF IRON ORE (EXCLUDING MANGANIFEROUS ORE) INTO THE UNITED KINGDOM (TONS).

From—	1912.	1913.	1920.	1922.
Canada	16,149	11,542	—	—
Newfoundland and coast of Labrador	18,511	100,346	26,469	—
Other British Possessions	98	12	4,166	80
Total from British Possessions	34,758	111,900	30,635	80
France	170,697	327,234	208,711	235,524
Greece	184,138	203,643	39,420	19,781
Norway	402,106	487,799	155,087	166,315
Russia	73,046	75,294	—	—
Spain	4,139,028	4,525,843	4,102,892	1,650,863
Spanish ports in North Africa	—	—	187,516	49,315
Sweden	355,455	366,691	456,115	320,883
Algeria	747,887	759,461	864,305	694,936
Tunis	238,912	279,071	314,424	207,343
Other foreign countries	93,274	93,669	59,777	80,342
Total from foreign countries	6,404,543	7,118,705	6,388,247	3,425,302
Total	6,439,301	7,230,605	6,418,882	3,425,382

The ores are imported into Scotland, the North-East Coast, the North-West Coast, and South Wales. On the North-East and North-West Coasts the imported ore supplements the home supplies, while in Scotland and South Wales the imported ores have practically replaced them. The following table shows the ports of the United Kingdom into which iron ore was imported in 1912, 1913, 1920, and 1922.

IMPORTS OF IRON ORE BY GROUPS OF PORTS (TONS).

	1912.	1913.	1920.	1922.
Scotland:				
Ardrossan	276,152	387,973	302,779	122,917
Ayr	166,637	146,761	72,821	3,122
Glasgow	984,134	1,122,023	891,833	290,678
Grangemouth	175,101	198,927	288,203	110,552
Troon	65,658	73,261	82,181	3,650
England and Wales:				
North-East:				
Hartlepool	355,422	382,612	194,367	63,404
Middlesbrough	1,814,320	2,087,700	1,583,382	1,410,953
Newcastle*	530,949	543,803	389,286	140,360
Stockton	222,881	202,116	87,740	43,059
Sunderland	124,170	140,699	237,824	24,932
North-West:				
Barrow-in-Furness	173,878	245,709	353,488	103,821
Chester	1,600	894	3,174	890
Lancaster	26,210	33,416	80,116	2,458
Maryport	107,164	133,499	153,957	74,816
Whitehaven	—	—	1,644	—
Workington	2,085	6,064	33,133	26,099
South-West:				
Cardiff	746,100	765,955	691,599	351,453
Newport	537,761	657,122	487,321	249,416
Port Talbot	70,366	78,688	68,039	136,411
Swansea	61,727	76,204	68,318	85,868

FUEL.

The coal resources of Great Britain are, of course, very large, but except in Scotland and in some parts of the Midlands, coke and not coal is used to smelt the ore, and it is not all coal by any means that will provide good coke, nor all coke that is suitable for foundry or blast furnace purposes. "The finest coking coals in Great Britain, and possibly in the world, are those found in the western areas of the Durham coalfields, which furnish the coke required for the blast furnaces of Durham and Cleveland."†

Good coking coal is one of Britain's chief assets and should be conserved; for it is very undesirable that coal which will produce a good metallurgical coke should be used for other purposes. The coke required for smelting iron ore in blast furnaces is termed "metallurgical coke," and its qualities are thus described in the Report of the Imperial Mineral Resources Bureau on Coal, Coke, and By-Products:

* Including Shields.

† *I.M.R.B. Report on Coal, Coke, and By-Products*, 1913-1919, Part I., p. 16.

"The essential characteristic of a good blast furnace coke (apart from low ash content) is a peculiar combination of strength and porosity, such that the fuel, while capable of withstanding the weight of the superincumbent materials in the furnace, at a depth of some 65 or 70 feet below the "stockline," shall nevertheless be sufficiently porous to be both easily penetrated by the ascending furnace gases and rapidly consumed by the blast at the tuyere level; and the fuel should also be as resistant as possible to the attack by carbon dioxide in the upper part of the furnace, which leads to the production of a quantity of carbon monoxide and to a corresponding waste of fuel."

Formerly, metallurgical coke was produced in a beehive oven which allowed the gas to escape without its valuable constituents being extracted. Great Britain and even the United States were slow in following Germany in adopting the by-product oven, under the impression that the coke produced in the by-product oven was not so good as that produced by the older method. This prejudice has now been overcome and beehive ovens are fast disappearing in favour of the more efficient by-product ovens, which not only yield valuable by-products (tar, pitch, sulphate of ammonia, toluol, etc.), but actually yield a higher proportion of coke per ton of coal used. The output of metallurgical coke in each of the last ten years has been as follows:

1913	12,798,996 tons.	1918	13,121,311 tons.
1914	11,050,256 ,,	1919	11,681,153 ,,
1915	11,908,940 ,,	1920	12,611,435 ,,
1916	13,288,474 ,,	1921	4,573,970 ,,
1917	13,555,051 ,,	1922	9,035,741 ,,

In 1922, on the average, 1 ton of coal carbonized realized 13·6 hundredweights of coke.

In 1913 there were still over 13,000 beehive ovens in use in the United Kingdom out of a total of 21,000, whereas in 1922 the number of beehive ovens was only 2,687 out of a total of 10,897, and the number is still rapidly declining. The coke ovens are now in most cases erected in the neighbourhood of the blast furnaces, where it is possible to utilize to the greatest extent the initial heat required to carbonize the coal and the surplus gas from the by-product ovens. Surplus gas from by-product ovens is employed for public lighting at Birmingham, Leeds, Little Hulton, Middlesbrough, and Sheffield.

Limestone.

On the average nearly ½ ton of limestone is used for fluxing purposes in smelting pig iron.

Limestone is, fortunately, found in most counties of Great Britain, and perhaps one-third of the total quantity raised is used in the manufacture of pig iron; the remainder is used chiefly in building and road-making. In 1922 approximately 9½ million tons of limestone were raised, nearly 2 million tons of which were in Derbyshire, 890,000 tons in Yorkshire, 830,000 tons in Durham, 761,000 tons in Somersetshire, and 709,000 tons in Glamorganshire.

CHAPTER III

THE RESOURCES FOR THE MANUFACTURE OF IRON AND STEEL IN THE BRITISH DOMINIONS

SINCE the countries of the British Commonwealth provide a market for nearly one-half of the iron and steel exported from the United Kingdom, the question of the iron ore resources of the Dominions and the possibility of their developing an iron and steel industry of their own is of the first importance, not only to the Dominions themselves, but also to the iron and steel industries of this country. Most of the Dominions, in fact, possess iron ore in sufficient quantities to justify exploitation, and the Report of the Imperial Mineral Resources Bureau considers that Australia and India will eventually be in a position not only to supply all local demands, but will also have a surplus for export. The great drawback in all the Dominions at the present time, however, is that the demand is relatively so small and of so diverse a nature that large-scale production is impracticable, and it is, therefore, impossible to compete with the highly efficient and larger plants of America, Great Britain, and the Continent.

The exports of iron and steel from Great Britain to the principal Dominions in 1913, 1920, and 1922 were as follows:

		1913 (*Tons*).	1920 (*Tons*).	1922 (*Tons*).
British India		860,900	659,400	652,400
Canada		187,300	30,800	113,700
South Africa and Rhodesia		260,700	162,900	111,400
Australia		567,100	193,800	374,300
New Zealand		154,100	70,400	90,600
Other British Possessions		277,200	293,000	302,700
Total	Tons	2,309,200	1,410,300	1,645,100
	Value (£)	26,931,600	59,373,700	32,092,800
Total to foreign countries	Tons	2,660,100	1,840,900	1,752,100
	Value (£)	28,419,100	69,533,700	28,768,800
Grand total	Tons	4,969,300	3,251,200	3,397,200
	Value (£)	55,350,700	128,907,400	60,861,600

Since, in the early stages at least, it is impossible for the Dominions to manufacture in competition with older producing countries, they have in many cases sought to encourage the home industry either by means of a protective tariff, or by means of bounties on home-produced iron and steel, or by both.

INDIA

It will be seen from the table given above that British India takes more iron and steel than any other of the Dominions, but for its size and population India is relatively a small consumer of iron and steel, having, in fact, with the exception of China, the lowest consumption of iron per head of any civilized country. That iron was known in India at a very early date is evidenced by the well-known iron pillar at Delhi, which is 50 feet high and 16 inches in diameter, and dates back, according to Brough,* to at least 912 B.C., although some authorities, notably Professor Turner, give a considerably later date. Until comparatively recently local needs were met by the native industry, which produces iron of such purity and malleability that it has been able to some extent to withstand the competition of imported iron. The native industry is, however, handicapped by primitive methods of mining and smelting, for it is only the softer varieties of ores which can be made use of and the furnaces are of small capacity, blown by leather bellows, and the maximum yield reported for a single furnace is about 30 tons per annum.

It is not surprising that the whole area of 1,773,168 square miles which constitutes India has not yet been adequately prospected for iron ore, and that no estimate exists of the total iron ore resources of India. Sufficient has been done, however, to prove that very large deposits of iron exist. The most extensive deposits as yet found are in the Province of Bihar and Orissa, where it is worked on the Kolhan Estate, Singhbhum, for the Bengal Iron and Steel Company, and in Mayurbhanj, also in the Singhbhum district, for the Tata Iron and Steel Company.

The hematite deposits in the Singhbhum district have recently been examined by Mr. Ernest Parsons for Messrs. Villiers of Calcutta, who came to the conclusion that the area contains at a minimum 3,000 million tons of ore containing 60 per cent. or more of metallic iron.

India, therefore, possesses extremely valuable iron ore resources. Moreover, they are of a very high grade and can be easily and cheaply worked in modern blast furnaces, and the fact that they are relatively near to the Indian coalfields renders it extremely probable that India will one day be one of the world's greatest iron-manufacturing centres. In the Report of the Imperial Mineral Resources Bureau the conclusion is arrived at that "it would not seem to be far distant when India will be self-supporting as regards iron and steel and will probably be exporting pig iron, which, in the opinion of those best able to judge, can be produced comparatively cheaply owing to the low assembly costs consequent on the close proximity of raw materials and the cheap rates of freight."

The only drawback at present, and one which in all probability will be overcome, is that the quantity of coal of good coking quality is strictly limited, and a Government Committee which considered the question of the supplies of metallurgical coke and reported in June of 1920 uttered the warning that it would be necessary to conserve the supplies of coking coal and to use coal of lower

* *Journal of the Iron and Steel Institute*, No. 1, for 1906.

grade wherever possible, for at the present rate of increase in consumption the known reserves of high-grade coking coals, which were put at 2,000 million tons, would be exhausted in forty years.

The first attempts to manufacture iron on a large scale were based on charcoal as a fuel, and were made in Bengal in 1777 and in Madras in 1825, but failed because of the depletion of the forests in the vicinity of the works. Since the existence of coal capable of producing good metallurgical coke has been proved, two well-known iron works have been erected where iron ore deposits occur relatively near to the coalfields, and others are in contemplation.

The works already in existence are the those the Bengal Iron and Steel Company near Barakar in Bengal, and of the Tata Iron and Steel Company at Jamshedpur in Bihar, while the works contemplated, or in course of erection, are for the Indian Iron and Steel Company at Hirapur; the Eastern Iron Company, near the Jherria coalfields; and the United Steel Corporation of Asia at Manoharpur, near the western boundary of Singhbhum. There is also a charcoal blast furnace at Benkipur in Mysore, the property of the Mysore State, and a works for producing iron and steel castings from Indian and imported pig iron. The descriptions which follow of these various works are taken in the main from the Report of the Imperial Mineral Resources Bureau, where acknowledgment is made to the journal of the Records of the Geological Survey of India, to Messrs. Martin and Company, managing agents for the Bengal Iron and Steel Company, and to the manager of the Tata Iron and Steel Company.

The Bengal Iron and Steel Company.

This company was founded in 1874 as the Bengal Iron and Steel Works Company, but came to an end in 1879, after producing some 13,000 tons of pig iron. After a period of Government ownership the works were sold to the Bengal Iron and Steel Company in 1889, which was reconstituted as the Bengal Iron Company, Ltd., in 1919. For many years the Raniganj coalfield supplied most of the ores used, but as these ores are high in phosphorus, their use has been given up, and the output has declined since 1915, when the output was only 2,243 tons compared with an average of 72,988 tons during the five years 1905 to 1909. The works are now entirely supplied with ore from the company's mines on the Kolhan Estate, Singhbhum, and at Ghatsila and Dhalbhum. The main deposits are known as Pansira Hill and Budabura Hill, a little south-east of Manharpur on the Bengal-Nagpur Railway.

The ore is a high-grade hematite, with the following average analysis:

Iron	64·00	per cent.
Silica	2·10	„
Lime	0·15	„
Alumina	1·25	„
Magnesia	0·18	„
Manganese oxide	0·05	„
Sulphur	0·002	„
Phosphorus	0·05	„

The company has now five furnaces with an annual capacity of 175,000 tons of pig iron per annum. The pig iron produced has the following average analysis:

	Grades 1, 2, and 3 (per Cent.).	*Foundry Pig 3 and 4 (per Cent.).*
Graphitic carbon	3·13	2·98
Combined carbon	0·23	0·32
Silicon	2·99	2·26
Phosphorus	1·20	1·21
Manganese	1·40	1·13
Sulphur	0·022	0·03

In addition to the blast furnaces there are iron foundries for pipes, sleepers, and general and special castings, and a machine shop for machining castings.

The company also owns its own coke ovens, which are of the Simon-Carves regenerative type.

The Tata Iron and Steel Company.

The works of the Tata Iron and Steel Company are situated at Jamshedpur, 153 miles from Calcutta. The plant consists of coke ovens, blast furnaces, steel furnaces, rolling mills, power house, foundries, machining shops, forges, etc.

The plant of the company either in actual operation or in process of installation was thus described in a descriptive advertisement in *The Times* of May 11, 1923:

"The coke oven plant consists of 150 Wilputte, 180 Coppee, and 50 Koppers ovens, producing 800,000 tons of coke per annum. In connection with the more modern portion of this installation are installed a sulphuric acid plant and a by-product recovery apparatus producing ammonium sulphate, tar, pitch, benzol, and other by-products.

"The four blast furnaces, together with a fifth shortly to be blown in, will give a total annual output of 600,000 tons of pig iron and about 4,000 tons of ferro-manganese. Two of these furnaces are of the latest American type, and each has a potential output of 500 tons per day.

"There are seven fixed open-hearth steel furnaces of the Siemens-Martin basic type, of 60 tons capacity, and two duplexing furnaces with their corresponding converters, having a capacity of 570,000 tons per annum. In the old and new rolling mill departments are two blooming bills, a 28-inch mill, a rail and structural mill, a sheet bar and billet mill, a plate mill, and a sheet mill, having a total output capacity—in the various forms produced by the individual mills—of 600,000 tons of steel per annum. Sections are all rolled to the British standard specification, and comprise 24-inch joists, 100-pound rails, channels, angles, and other sections; boiler and ships' plates; tin bar for the subsidiary tinplate company; and sleeper plates for the sleeper press.

"It is of interest to note that the sheet bar and billet continuous mill, built by the Morgan Construction Company of America, having six stands of 24-inch and six stands of 18-inch rolls, is similar to the mill installed by Messrs. Steel Peech and Tozer, Ltd., at their Templeborough works during 1919—an event which caused very considerable interest in engineering circles at the time."

The ore is obtained from the Guramaishini Hill some 40 miles from Jamshedpur, where 15 million tons of ore have been proved to date, of which the average composition is—

Iron	60·00 per cent.
Phosphorus	0·082 ,,
Insoluble residue	5·83 ,,
Manganese	0·42 ,,

To utilize the various materials produced by the company a number of subsidiary companies which will undertake manufacture at Jamshedpur have been, and are being, formed. These include the Calcutta Monifieth Works, which are already producing machinery for the jute industry; Enamelled Ironware, Ltd., which will manufacture plates, cups, and other utensils; the Agricultural Implement Company, which will make ploughs, etc.; the Indian Steel Ware Products, Ltd., the Enfield Cable Company, the Hume Pipe and Construction Company, and the Tinplate Company of India, which will produce tinplates chiefly for use by the Burma Oil Company and other oil companies in India.

This last concern is probably the most important of the several industries entered into by the Tata Company, and a description of the works was given in the *Iron and Coal Trades Review* of February 29, 1924. The plant adjoins the works of the Tata Iron and Steel Company at Jamshedpur and has a capacity of 30,000 to 33,000 tons of blackplates per year. Careful attention was given to the layout and design of the plans in order that operations could be carried on under any and all conditions of climate in India. Electric drive is used throughout and the mills are heavy and fast.

The tinhouse installation consists of six automatic combined pickling and tinning machines each equipped with a conveyer, which delivers the plates into the warehouse ready for inspection. There are nine cranes and one electric hoist, which serve every department except that for black pickling. During the latter part of 1922 and the early part of 1923 about ninety experienced tinworkers from Wales were taken to India for the operation of this plant.

A process of dilution of labour was then carried out, and Indian workers were employed under guidance of the experienced tinworkers. The first mill was successfully started up on January 12, 1923, and on January 29 a second mill commenced operations. These two mills were active continuously until September, 1923, when between this date and December the remaining four mills were started up. The plant for the year 1923 hot-rolled 213,940 boxes of sheared and acceptable blackplate.

The United Steel Corporation of Asia, Ltd.

The information concerning the plans of this company was kindly communicated by Messrs. Cammell Laird and Co., Ltd. This corporation was formed by Messrs. Bird and Co. of Calcutta and Messrs. Cammell Laird and Co., Ltd., and the intention of the corporation is to convert iron ore into finished steel in a form in which it is most saleable by a steel-producing concern. This form is, without doubt, the rolled form, and it is, therefore, the purpose of the corporation to produce rails, both heavy and light, beams, channels, angles, and all other sections or shapes which may be required, from the largest to the smallest of the British standard sections. Plates will also be produced, and these will be of sizes and thicknesses suited to the manufacture of ships, locomotives, wagons, etc. A separate section of the works will be devoted to the manufacture of thin plates and sheets, either plain or corrugated, black or galvanized; it is also proposed to roll the heavier classes of wire, wire rods, etc.

As regards the capacity of the proposed works, the conclusion was reached that the Indian market should readily absorb about 500,000 tons of rolled material per annum over and above that which India was already producing, but this tonnage would require a works of a very much greater size than could be contemplated at the commencement of a new company, and it was, therefore, decided to go ahead with a scheme for a works with an output of approximately half of this figure—viz., 225,000 tons per annum—without losing sight of the fact that in the not very distant future an expansion to the full figure of 500,000 tons per annum would be desirable. The scheme, therefore, which has actually been prepared is on the basis of 225,000 tons of rolled material per annum.

The plant to be installed included blast furnaces, coke ovens, steel-melting furnaces and rolling mills, including the whole of the auxiliary machinery necessary for the equipment of such a plant, and the generation of the whole of the electric current required in its working.

The difficulty of raising capital is the only present obstacle to making a start. This may, of course, at any moment be overcome, and in that case the scheme would be put into operation.

General.

The production of pig iron and steel in India from 1914 onward has been as follows:

Year.	*Pig Iron (Tons).*	*Steel Ingots and Castings (Tons).*
1914	234,700	66,600
1915	270,000	103,500
1916	246,600	131,100
1917	251,600	164,000
1918	264,700	183,600
1919	320,000	186,900
1920	312,400	156,200
1921	371,100	182,700
1922	340,200	150,500

IMPORTS OF IRON AND STEEL, 1914 AND 1920–1922 (TONS).

	Year ending March 31.	U.K.	Germany.	Sweden.	Belgium.	U.S.A.	Other Countries.	Total.
Pig iron	1914	12,129	75	—	—	—	50	12,254
	1920	4,155	—	—	—	—	—	4,155
	1921	8,858	90	—	—	—	6	8,954
	1922	7,858	1,172	—	13,492	251	320	23,093
Angles, rods, etc. ..	1914	17,598	14,394	209	12,485	522	19	45,227
	1920	10,901	—	—	219	4,070	394	15,584
	1921	22,142	475	66	2,454	3,660	119	28,914
	1922	4,869	1,750	—	6,608	3,409	2,318	18,954
Bars, channel ..	1914	33,817	85,310	2,985	108,028	1,148	67	231,355
	1920	29,379	773	766	8,868	38,397	2,807	80,990
	1921	89,426	9,770	1,750	44,842	17,475	4,247	167,510
	1922	25,049	20,343	545	81,026	12,954	13,706	153,623
Girders, beams, etc.	1914	56,176	21,554	—	9,817	368	1,727	89,642
	1920	20,435	—	—	—	2,205	28	22,668
	1921	63,696	210	—	7,846	6,471	137	78,360
	1922	21,720	1,975	—	29,050	2,357	2,935	58,037
Hoops and strips ..	1914	21,757	5,153	—	2,560	923	397	30,790
	1920	16,488	—	—	123	11,265	179	28,055
	1921	18,850	224	—	298	3,746	113	23,231
	1922	12,055	1,394	—	1,445	2,632	299	17,825
Nails, rivets, and washers	1914	7,291	5,338	1,159	3,315	3,075	4,898	25,076
	1920	4,036	—	642	50	2,285	979	7,992
	1921	7,450	110	1,786	719	1,022	2,060	13,147
	1922	3,470	876	719	1,367	201	542	7,175
Railway rails, fish-plates, and sleepers	1914	199,912	1,287	—	1,186	—	—	202,385
	1920	47,017	—	—	—	160	—	47,177
	1921	69,342	—	—	268	5	—	69,615
	1922	106,547	496	—	1,208	33	—	108,284
Rails, chain, and fish-plates (except railway rails)	1914	4,594	8,254	—	4,919	6	7	17,780
	1920	1,769	—	—	—	5,220	—	6,989
	1921	12,877	—	—	1,051	4,555	426	18,919
	1922	7,372	7,488	10	3,605	2,669	910	22,054
Pipes and fittings (cast and wrought)	1914	54,306	7,549	—	1,789	10,945	56	74,645
	1920	28,886	—	—	—	27,152	92	46,147
	1921	30,366	255	—	120	25,480	1,130	67,335
	1922	23,090	2,843	12	763	29,929	1,537	58,174
Plates and sheets ..	1914	366,440	41,472	—	19,781	3,015	329	431,037
	1920	132,424	103	—	3,711	29,760	681	166,679
	1921	172,116	1,722	—	7,714	31,337	2,485	215,374
	1922	134,281	15,182	10	16,383	6,458	1,830	174,144
Wire and wire manufactures	1914	2,858	3,364	—	1,346	1,433	818	9,819
	1920	6,065	—	—	109	9,891	476	16,541
	1921	8,065	2,126	36	3,021	3,879	815	17,942
	1922	2,864	5,323	—	4,337	561	278	13,363
Total (including other items)	1914	811,198	201,390	4,496	172,234	22,035	9,280	1,220,633
	1920	316,363	876	1,634	13,240	134,708	7,302	474,123
	1921	567,633	15,119	4,090	69,175	112,987	12,501	781,505
	1922	387,095	60,062	2,194	161,478	83,830	26,406	721,065

FINISHED STEEL PRODUCTION, 1916–1922 (TONS).

	1916.	1917.	1918.	1919.	1920.	1921.	1922.
Rails (heavy)	35,097	70,194	66,899	58,928	51,535	73,561	61,497
Rails (light)	1,498	2,476	4,197	4,254	4,452	9,508	2,089
Sleepers and fishplates ..	2,217	3,899	3,498	2,866	1,968	4,127	2,762
Angles, channels, and tees	12,680	8,118	14,593	17,953	14,856	9,412	11,256
Girders, joists, and beams	25,247	2,088	5,950	18,210	19,154	9,561	15,218
Rounds, squares, and flats	14,574	18,264	25,314	21,757	18,346	15,465	17,620
Total	91,493	105,039	120,451	123,968	110,311	121,634	110,442

EXPORTS AND IMPORTS.

India has already developed a considerable export trade in pig iron, and in the year 1917 exported as much as 102,329 tons, of which 69,000 tons went to Japan, 15,800 tons to Australia, and 9,300 tons to Hong Kong. In 1923 the exports of pig iron amounted to 181,500 tons, of which 150,776 tons went to Japan.

As showing the demand for iron and steel in India, in addition to the home supply, the table on p. 49 gives the imports of iron and steel for the years ending March 31, 1914, and 1920 to 1922, detailing the different sources of supply.

AUSTRALIA

It has been known for a long time that there are large deposits of iron ore in the Commonwealth, and the reserves are thus summarized in the Report of the Imperial Mineral Resources Bureau dealing with that Dominion:

State.	*Actual Iron Ore Reserves (Thousands of Tons).*	*Probable Iron Ore Reserves (Thousands of Tons).*	*Possible Iron Ore Reserves (Thousands of Tons).*
New South Wales	53,017	—	—
Victoria	742	1,150	—
Queensland	25,675	20,000	20,308
Western Australia	155,950	450,000	21,000
South Australia	67,645	32,299	32,000
Tasmania	41,900	—	—
Total	344,929	503,449	73,308

Although, as will be seen, iron ore deposits exist in all the States, production during recent years has been reported only in New South Wales, Queensland, and South Australia.

New South Wales.

In New South Wales the ores are found in various localities, but the most important are at Cadia, where the reserves are estimated at about 39 million tons, and at Coombing Park, near Carcoar, where the reserves are estimated at 3 million tons. The latter deposit, which has been quarried to a considerable extent by Messrs. Hoskins Brothers, whose smelting works are established at Lithgow, contains 55·8 per cent. of metallic iron. The iron content of the ore at Cadia varies between 61·38 per cent. and 49·1 per cent. The other deposits in the State, though in many cases higher in iron content, are of less extent.

Victoria.

The iron ores of Victoria have been known to exist for many years, and in 1881 a blast furnace was erected near Lal Lal on the Moorabool River and produced iron which was used for truck wheels and stamper shoes at the Ballarat Mines. The fall in the price of the metal, however, led to the closing of the works, and in the Report of the Secretary for Mines for 1905 it was stated that there did not seem any prospect of the deposits being profitably worked without special assistance to the industry.*

Queensland.

Iron ore is widely distributed throughout Queensland, but except at Mount Leviathan and Mount Philp does not occur in great bulk. The report puts the actual reserves at Mount Philp (a range of hills and peaks a few miles south-west of Balara) at 20 million tons actual, 20 million tons probable and a further 20 million tons possible; the iron content is over 50 per cent. The reserves at Mount Leviathan amount to 2,000,000 tons with an iron content from 56·5 to 62 per cent. Queensland also possesses supplies of fuel and limestone, and, as will be seen below, contemplates importing ores from Koolan and Cockatoo Islands and building up a local iron industry.

Western Australia.

The geographical position, and the absence of suitable coalfields in Western Australia, militates against the successful exploitation of the many iron ore deposits which are known to exist in that State, so that up to the end of 1919 less than 60,000 tons had been raised altogether. The largest known deposits up to the present time are those of Koolan and Cockatoo Islands in Yampi Sound, about 100 miles north of Derby, and these appear likely to play a prominent part in the immediate future, for the Queensland Government has purchased the deposits of Cockatoo Island and has established State iron and steel works at Bowen, to which the ore will be shipped from Yampi Sound to be blended with ore from Cloncurry.

* *Official Year Book of the Commonwealth of Australia*, No. 16, 1923, p. 811.

It is estimated that the actual reserves, above high-water mark, on Koolan Island amount to 76,500,000 tons, and on Cockatoo Island to 20,750,000 tons, while the probable reserves for the two islands together are put at 450,000,000 tons. Analyses show that the iron content is between 60 and 70 per cent. in Koolan Island and between 50 and 70 per cent. on Cockatoo Island. A report recently issued upon these deposits states that operations, to be profitable, must be carried on upon a large scale, and suggests that a strong combination of iron-smelting and shipping interests in Great Britain would be most likely to handle it to advantage.

South Australia.

South Australia possesses a number of iron ore deposits of considerable value, the best known being deposits at Iron Knob and the adjacent Iron Monarch, which between them are estimated to possess 67 million tons of actual reserves and considerable probable and possible reserves. The grade of ore mined has been found to average about 68·5 per cent. of metallic iron, and the total production from Iron Knob and Iron Monarch, since they were first opened up in 1899 to the end of 1919, is 1,820,000 tons, of which 1,010,600 tons were consumed as flux at Port Pirie and 810,000 tons were shipped to New South Wales for the manufacture of pig iron.

The War gave a great impetus to the iron and steel industry in Australia. Prior to the War, practically all her iron and steel requirements were met by imports from Europe and America. Taking 1912 as a typical pre-war year, imports of pig iron were valued at £230,640, of which £189,131 came from Great Britain and £28,226 from India. Imports of other iron and steel products were valued at £8,353,574, of which £5,878,852 came from Great Britain, £1,075,483 from United States, £995,275 from Germany, and £332,425 from Belgium.

Although the iron and steel industry started with the erection of blast furnaces in Mittagong in New South Wales as early as 1848, the output did not assume considerable proportions until 1915, when the establishment of the Broken Hill Proprietary Company's Works at Newcastle marked a new period in the manufacture of iron and steel in Australia. The works now possess three blast furnaces of a normal daily producing capacity of 1,300 tons, and a fourth furnace of 100 tons for the production of foundry iron. There are seven 65-ton basic open-hearth furnaces capable of producing 8,000 to 10,000 tons of ingot steel weekly. The works are supplied with a 35-inch blooming mill for the production of blooms, plates, etc.; a 28-inch rolling mill for the manufacture of heavy rails, structural steel, billets, etc.; an 18-inch mill for making light rails, structural shapes, fishplates, and heavy sections of merchant bar and billets; a 12-inch mill and an 8-inch mill, each for merchant bars, etc.; a continuous rod mill for the production of wire rods, and a fishplate mill. A steel foundry, containing one acid open-hearth furnace, and a cupola furnace for iron castings, with a direct metal foundry which takes the hot metal from the blast furnaces, supply all necessary castings.

The company also possesses 224 by-product coke ovens, and connected with this department are the tar, sulphate of ammonia, and benzol plants.

The output of pig iron from the Newcastle works amounted in 1921 to 262,312 tons and of steel ingots to 255,437 tons.

The Lithgow iron works comprise two blast furnaces stated to have a joint capacity for about 3,000 tons of pig iron per week.

The following subsidiary industries have either been established or are projected at Newcastle:*

A plant for the manufacture of railway tyres, axles, and other products, having a capacity claimed to be sufficient to supply the whole requirements of the Australian railways in tyres and axles, has been erected by the Commonwealth Steel Products Company; the Austral Nail Company has erected a plant for the production of wire for fencing and general purposes; Messrs. Rylands have also established a plant for the manufacture of wire netting and other materials, Messrs. Lysaght have established works for the manufacture of galvanized and black sheets; a tinplate works is also contemplated. In 1916 the Australian Electric Steel Company, Ltd., introduced electric methods of smelting into Australia.

The annual production of coal, iron ore, pig iron, and steel since 1912 has been as follows:

Year.	*Coal (Tons).*	*Iron Ore (Tons).*	*Pig Iron (Tons).*	*Steel Ingots and Castings (Tons).*
1912	11,725,763	113,989	32,677	—
1913	12,414,882	173,073	46,563	—
1914	12,442,152	226,028	75,150	24,000
1915	11,412,587	417,744	146,532	62,000
1916	9,809,172	324,144	127,591	108,000
1917	10,197,522	449,860	148,419	150,000
1918	10,883,146	416,302	209,253	142,000
1919	10,455,096	437,260	253,755	178,000
1920	12,805,603	605,626	344,000	167,000
1921	12,798,302	689,275	352,365	209,000

With an increasing production, Australia has of late years been in a position to export pig iron, so that the value of pig iron exported, which was only £881 in 1912, amounted to £164,419 in 1920, of which £147,538 went to Japan and £14,751 to New Zealand.

Outside competition, especially from the United States, and possibly later from Japan and China, is feared, and the Government has, therefore, from time to time passed measures for the encouragement of the local iron and steel industry by means of bounties and later also by means of protective duties. The first measure of this kind was the Manufacturers Encouragement Act, which came into force on January 1, 1909, and provided for the payment up to June, 1914, of bounties of 12s. per ton on Australian pig iron, puddled bar iron, and steel, and of 10 per cent. on the value of galvanized sheet or plate, wire netting, wire, and iron or steel pipes or tubes. From June 30, 1909, to June 30, 1915, a total sum of £173,671 was paid in respect of these bounties. The Iron Bounty

* *Report of I.M.R.B.*, part v., p. 76.

Act, 1914-15, repealed the Act just referred to and fixed the rate of the bounty up to the end of 1916 at 8s. per ton and limited the total amount payable to £60,000. Provision was also made for the transfer to the State, if required, of lands, buildings, etc., used in the manufacture of pig iron. New South Wales is the only State where the bounty has been claimed, and in the three years 1915-1917 the bounties amounted to £19,808, £24,465, and £11,454 respectively.

The Iron and Steel Bounty Act of 1918 provided for bounties on galvanized and black sheets and arranged for the bounty to vary according to the rate of freight from the United Kingdom to Australia. This was superseded by the Iron and Steel Products Bounties Act, 1922, under which bounties are payable on fencing wire, galvanized sheets, wire netting, and traction engines made in Australia. It is essential that these articles be made from materials produced and manufactured in Australia unless imported material is authorized after enquiry and report by the tariff board. The total payments in any one year must not exceed £250,000; the rates of bounty are—on fencing wire and galvanized sheets, £2 12s. per ton; on wire netting, £3 8s. per ton; and on traction engines, £40 to £90 each according to brake horse power. A tariff barrier has now also been erected which varies from £1 per ton on pig iron to £3 5s. per ton on plain plates and sheets when imported from Great Britain, and is 50 per cent. to 100 per cent. higher when imported from other countries. The demands for iron and steel and the sources of supply are indicated by the figures on p. 55.

NEW ZEALAND

New Zealand contains a number of deposits of iron ore, though, so far as has at present been ascertained, only two groups are large enough or contain ore of a sufficiently high grade to be of economic importance. Much more work will have to be done to enable reliable figures of reserves to be given, but they are put approximately at 70 million tons, of which 64 million tons are in the Parapara district, the average iron content of which, as obtained from thirty-four samples, is 51·79 per cent.

The report of the Imperial Mineral Resources Bureau states that the demand for iron and steel in New Zealand is at present about 100,000 tons per annum, but that the lack of suitable coking coals has been against the Dominion manufacturing her requirements locally. One factor which tends to encourage local manufacture, however, is the geographical isolation and remoteness of the Dominion, and in 1914 Parliament passed an Iron and Steel Industry Act providing £150,000 to be devoted to the encouragement of the manufacture of iron and steel in the Dominion. The amount was to be expended by way of a royalty of 12s. per ton on pig iron and 24s. per ton on steel produced direct. Nothing definite was done towards the development of an iron and steel industry, on account of the War, but the Act of 1914 has since been extended to March 31, 1931, and it was announced in the Dominion Parliament towards the end of 1920 that parties were ready to consider investment of the necessary capital to erect iron and steel works at one or

PRINCIPAL IMPORTS OF IRON AND STEEL INTO AUSTRALIA BY PRODUCT AND COUNTRY, 1913 AND 1920–1922 (TONS).*

Product.	Year.	Imported from						
		U.K.	Belgium.	France.	U.S.A.	Canada.	Other Countries.	Total.
Pig iron	1913	39,715	31	—	6,183	—	8,268	54,197
	1920	1,985	—	—	685	11	—	2,681
	1921	932	—	—	313	—	—	1,245
	1922	3,101	151	—	—	—	3	3,255
Ingots, blooms, billets ..	1913	1,915	3,964	—	15	—	3,603	9,497
	1920	955	—	—	1	—	—	956
	1921	395	—	996	—	—	8	1,399
	1922	1,930	134	237	2	—	—	2,303
Bars, rods, angles ..	1913	75,174	17,267	339	9,605	4	29,303	131,692
	1920	9,418	—	—	7,784	1,146	10	18,358
	1921	11,864	9,819	83	5,837	641	504	28,748
	1922	26,903	19,546	3,795	2,821	62	410	53,537
Hoops	1913	3,424	998	42	893	—	3,446	8,803
	1920	3,986	—	—	2,100	—	3	6,089
	1921	3,983	303	—	1,305	18	—	5,609
	1922	3,673	689	68	363	1	11	4,805
Girders	1913	37,708	552	37	5,105	5	4,310	47,717
	1920	5,617	—	—	5,052	99	4	10,772
	1921	6,175	108	20	5,605	82	—	11,990
	1922	10,173	156	87	708	188	51	11,363
Plates and sheets (plain)	1913	29,258	4,556	164	9,686	—	12,157	55,821
	1920	18,960	9	—	11,603	30	—	30,602
	1921	34,218	1,564	—	35,437	2,632	320	74,171
	1922	14,661	2,061	495	8,778	4	49	26,048
Plates (galvanized) ..	1913	104,500	156	15	5,104	—	68	109,843
	1920	53,333	—	—	8,933	110	—	62,376
	1921	52,761	—	—	2,287	—	—	55,048
	1922	52,208	9	—	1,287	—	—	53,504
Wire (barbed)	1913	679	15	—	1,495	19	864	3,072
	1920	915	—	—	2,814	—	—	3,729
	1921	1,353	250	125	8,233	115	2	10,078
	1922	202	626	—	3,240	106	24	4,198
Wire (plain)	1913	6,249	213	—	23,767	136	35,420	65,785
	1920	2,420	825	—	15,652	867	1	19,765
	1921	4,722	2,712	15	20,688	1,594	185	29,916
	1922	6,043	1,807	26	3,747	766	75	12,464
Nails	1913	2,213	1,073	—	420	—	732	4,438
	1920	1,041	—	—	1,821	71	76	3,009
	1921	1,241	30	1	535	99	307	2,213
	1922	1,027	87	4	426	55	176	1,775
Pipes and tubes	1913	9,156	6,090	—	17	—	791	16,054
	1920	11,977	—	—	5,015	1,646	113	18,751
	1921	18,027	60	—	12,626	3,518	68	34,299
	1922	12,124	59	—	6,409	1,533	76	20,201
Tinplates	1913	31,213	—	—	—	1	4	31,218
	1920	32,744	—	—	737	—	—	33,481
	1921	48,893	12	—	6,277	2	52	55,236
	1922	17,599	—	—	174	—	2	17,775

* The figures for 1913 are for the calendar year; those for 1920–22 are for the fiscal years ending June 30.

other of the main sources of supply. In 1922 the Onakaka Iron and Steel Company completed its smelting plant at Onakaka, near Collingwood, and made an experimental run, treating 160 tons of crude ore and obtaining 81 tons of pig iron. An analysis of the pig iron gave the following results: total carbon, 3·08 per cent.; graphitic carbon, 2·89; combined carbon, 0·19; silicon, 3·92; sulphur, 0·04; phosphorus, 0·22; manganese, 0·64. The pig iron is said to be very suitable for foundry purposes. The company has also completed sixteen beehive coke ovens, though it is now reported that the company has made satisfactory arrangements for a sufficient coke supply within the Dominion. The total output of coal in New Zealand in 1922 amounted to 1,857,819 tons.

SOUTH AFRICA*

When the story of African minerals is finally written, the coal and iron of Nigeria and the iron ores which abound in Tanganyika and Uganda, and in parts of Egypt and the Sudan, will have been properly prospected. It will then be possible to assess their true importance in the industrial development of the British Empire, but here they must be very briefly dismissed. However rich and extensive these ore deposits may be, they lie in the economic hinterland, away from transport facilities and the centres of white population, and in most cases far from suitable coal. In Nigeria both coal and iron are plentiful, and in 1918 coal with a steam-raising capacity equal to 80 per cent. of best Welsh was being exported from Lagos at 56s. per ton. The industrial prospects there are, however, in every way inferior to those of the Union of South Africa.

Conditions favourable to the Establishment of a Successful Iron and Steel Industry.

The success of a new industry depends upon four principal factors:

1. Cheap and abundant supplies of raw material.
2. The man-power factor, including technical experts, skilled workers, and cheap general labourers.
3. Command over capital sufficient to enable operations to be conducted on the most economical scale.
4. An assured demand at a price sufficient to tide the industry over the initial period of high production costs and uncertain results.

What are the prospects of a South African iron and steel industry considered in the light of these tests?

Raw Materials.

Our knowledge of the mineral resources of the Union itself is very far from complete, but enough has been done to convince business men and technical experts that an abundance of good coking coal and of excellent iron ore are to be

* The section on South Africa has been contributed by G. E. Lavin, B.A., F.R.C.I.

found in close proximity and can be very cheaply mined. Much detail is available in the volume issued by the Imperial Mineral Resources Bureau, and only a very brief summary can be attempted here.

(*a*) *Coal.*

The principal coal-bearing area of the Union is the Ecca deposit, which stretches like a great boot over North-Western Natal, South-Eastern Transvaal, and the Northern Free State. The leg runs from Estcourt on the spurs of the Drakensburg to Somkele, near St. Lucia Bay; the heel, from Belfast on the Delagoa Bay railway to Pretoria; the sole, from Boksburg and Vereeniging to Vierfantein; the toe and tongue back through Lindley, Vrede, and Klip River to Estcourt. This area is likely to prove of supreme economic importance to Africa, but other considerable coalfields exist in the Union. An offshoot of the Ecca field runs through the Limbombo plateau parallel to the Portuguese border for some 400 miles. Coal is also found in Zautpasberg and between the Pongola and Limpopo Rivers. Of more importance is the Kroomdrasi field astride the Nylstroom line, some 40 miles from Pretoria.

The other important coal-bearing area of the Union is the Molteno field in the Cape Province. The field is on an average about 30 miles broad, but its inferior quality and economic site both render it of less importance than the Ecca field. Lignite deposits have been found in some parts of the Western Province—*e.g.*, van Rhyns Dorp and Knysna.

Southern Rhodesia has been even more imperfectly prospected than the Union, but several important coalfields have been discovered. The chief of these are the Wanhill field stretching across the Livingstone railway to the Zambesi, the Lufua and Luana coalfields further north, and the great Luba deposit of lignite extending south-west from the Saryati River to the Zambesi. Wanhill yields an excellent steam-raising coal with good coking properties. It supplies Rhodesia's requirements, about 500,000 tons a year.

THE OUTPUT OF SOUTH AFRICAN COAL.

	1922.				1923 (*Eleven Months, January to November*).			
	Tons Sold.	*Value at Pit Mouth.*	*Average Value.*		*Tons Sold.*	*Value at Pit Mouth.*	*Average Value.*	
		£.	s.	d.		£.	s.	d.
Transvaal	5,380,294	1,509,701	5	7·34	6,223,040	1,523,540	4	10·76
Natal	3,618,093	1,670,304	9	2·80	3,926,343	1,556,768	7	11·16
Orange Free State ..	729,113	290,980	5	9·12	797,239	221,032	5	6·54
Cape Province ..	6,813	5,191	15	2·86	5,920	4,303	14	6·45
Union total ..	9,734,413	3,395,176	—		12,915,497*	3,714,521*	—	

The best South African coal for coking purposes is found adjacent to the principal deposits of iron ore. To produce the same amount of heat as can be

* Twelve months, January to December.

obtained from 100 pounds of best Welsh coal it requires: Dundee coal, 128 pounds; Indwe, 161 pounds; Vereeniging, 169 pounds. The Union railways have been run entirely on South African coal for about fifteen years, and there is a steadily expanding export trade with India and the Far East, South America, Sudan, etc.

The higher price obtainable for Molteno coal is due to local scarcity, that for Natal coal to its greater thermal efficiency. The royalty rights belong to the owner of the land. Natal coal is exported mainly through Durban, Transvaal coal through Laurenço Marques and Cape Town. In spite of the shallowness of most of the Transvaal mines and some of those in Natal and the cheapness of unskilled black labour, the export price of coal remains relatively high, owing to the expensiveness of land transport. The electrification of the Natal railways, now almost complete, will tend to cheapen the freights; improved bunkering facilities are being provided, and there are plans to develop a coaling port on the Zululand coast. The development of the northern part or "heel" of the Transvaal coalfields will depend upon the progress of South African industries. The Rand draws its coal mainly from the Witbank and Boksburg mines. Eastward from Witbank to Belfast the coal and iron belts of the Transvaal intersect each other.

(*b*) *Iron Ore.*

The principal iron-bearing strata sweep in a boomerang-shaped curve from Pretoria eastwards to Arlie, and are thus traversed by the Delagoa Bay railway-line for about 200 miles; this iron belt is some 40 miles wide, and in the central portion from Balmoral to Belfast coal is very abundant. Large deposits of iron ore of good quality together with suitable coal have been located at Ermelo, Kroomdraai, and near Dundee, but no coal has yet been found near the ore beds of Potchefstroom, Buffelshoek, and Arlie.

No comprehensive survey of the iron ore resources of South Africa is possible here, but a few particulars of one or two of the principal varieties of ore may be of interest.

1 The magnetic quartzites of the Pretoria series have been thus summarized by a competent observer:*

"The most important deposit in point of size is the stratified bed of highly siliceous and slightly oolitic ironstone found near the base of the Pretoria shales. Wagner estimates the quantity available by open-cast and adit mining in the vicinity of Pretoria alone to be over 400 million tons. To this must be added the known development of the same bed near Potchefstroom, Arlie, Prieska, and other places, so that it is safe to say that the reserves of iron ore containing something like 48 per cent. Fe, 18 per cent. SiO_2, 0·2 per cent. P, and 0·015 per cent. S, are of the order of 1,000 million tons or more. There is another very large deposit of banded ironstone situated at Buffelshoek, 70 miles West-North-West of Britz Station on the Pretoria-Rustenburg line and 60 miles West-North-West from Warmbath, containing persistent beds of hematite ranging in thickness from

* *I.M.R.B.*, "Iron Ore," part ii., British Africa, pp. 31-32.

6 inches to 21 feet with over 60 per cent. Fe, something like 4 per cent. SiO_2, 0·025 P, and 0·01 S. The available amount of this ore is not likely to be less than 50 million tons, with further large quantities of siliceous ore associated with it."

2. Titaniferous magnetite (of the Bushveld granite series) containing over 60 per cent. Fe and about 16 per cent. SiO_2, with 0·1 S and traces of phosphorus. This ore recurs at frequent intervals for 200 miles, from Rustenburg eastwards. Wagner estimates that there are about 2,000 million tons of this quality available.

These characteristic examples are sufficient to establish the quantity of workable ore available. In most cases the deposits are situated too far from the sea to permit of their export, although during the War Ermelo magnetite, containing 68·1 per cent. of metallic iron, was offered f.o.b. Durban at 40s. a ton. The cost of mining is low, for in places large quantities of the reef are exposed and in most others it dips very gradually, so that surface quarrying and shallow adit mining are all that is required. At the Pretoria Municipal Quarry the siliceous ore can be quarried and delivered at the furnace for 3s. 6d. a ton. The cost of adit mining is estimated at 6s. a ton and of underground mining at 10s. It is clear, therefore, that the most profitable way of utilizing the coal and iron would be the establishment of works in the vicinity. All the incidental raw materials are available.

(c) *Refractory Materials and Fluxes.*

Dolomite is very plentiful in most parts of the ore-bearing region. Transvaal magnesite is in composition almost identical with the best Austrian.* Limestone is obtainable in most districts. Good fluorspar is found in the North Transvaal, and of silica and manganese many local ores contain ample content.

The Human Factor.

(*a*) Metallurgical chemists and engineers familiar with steel works practice are scarce in South Africa, but could readily be attracted from England or America.

(*b*) The Union naturally lacks men of the type of those whose skill and inherited experience have made Cleveland and South Wales famous. When an adequate iron and steel works is established it will be necessary to induce a leavening of such men and their families to settle in the country. This would be a treble boon; it would tend to relieve the after-war congestion in the heavy industries in Britain; South African industry would profit by a healthy graft from a famous stem; and the men and their families would receive a safe start under conditions which put the highest premium on energy and skill.

(*c*) The unskilled general labour would certainly be provided by the natives. Strong in physique, but blessed with an easy-going nature, the South African native of Bantu descent requires constant supervision by a foreman who understands his language and habits. He has the stockbreeder's hatred of the underground, and prefers open-air work of as arduous a character and half the wage to mining. If properly housed and decently fed he works contentedly for a wage

* Carnegie and Gladwyn, *Liquid Steel* (Longman), p. 24.

of two or three shillings a day. Though lacking in application if left to himself, he has the negro's aptitude for imitation and speedily acquires manual dexterity. It is an open question whether the negro race will ever acquire the application, steadiness, and skill that distinguish the best white factory worker. At present he is in the Transvaal prevented by the colour bar from even attempting to do the work of the skilled white artisan.

Capital.

Given good faith and political tranquillity the market for capital is the world itself. A united South Africa gives every promise of material progress and success. At present the Union is passing through the necessary, if uncomfortable and inartistic, transition stage by which a people emerges from the repose of pastoral life to the fluttering existence of a financial and industrial organism. To cast off the chrysalis is always a painful and delicate operation. As a South African economist has pointed out,* "South Africa is passing away from a prevailingly mining stage of development, just as California and Victoria have already done." During the War much of the money advanced by British investors to finance South African railways and mines was repaid, and to-day half the gold mines are owned by South African shareholders. Furthermore, these mines are a wasting asset, and as they close down capital will seek other investments. Some of it has already found its way into the coalfields of the Union. This is the manufacturer's opportunity, provided he can offer an economically sound investment. There exists in South Africa no constant reservoir of liquid financial resources from which a couple of million could be drawn to provide the capital for a fully equipped iron and steel works, but were an established British steel firm to set the seal of its approval to the project a good deal of local capital would soon find its way into the undertaking. It remains to see whether South Africa's demand for iron and steel justifies such a step.

South Africa's Demand for Iron and Steel.

A young country requires three classes of iron and steel goods:

(*a*) Crude iron and steel products such as angles, bars, girders, plates, sheets, hoops, pipes, etc. Though these are the finished articles of the iron and steel works, they are the raw material for other industries. In 1922 the Union imported 87,316 tons of such material, valued at £1,876,610. Fencing wire worth £338,960 and standards to the value of about £100,000 were also imported. Most of the country's rail requirements were met by rails produced from scrap at Vereeniging.

(*b*) Finished articles of a comparatively simple nature. Hardware and cutlery, including wire rope, bolts, nails, etc., answer to this description. Goods of this sort to the value of some £1,500,000 were imported in 1922, about 62 per cent. being of British manufacture.

(*c*) Complicated and delicate machinery, such as locomotives, motor-cars power generators, etc.

* Lehfeldts, *National Resources of South Africa*, p. 30

A properly equipped iron and steel works producing its own pig iron and coke from the local raw materials could supply the Union's demand for (*a*). At a low estimate the annual demand, including rails, exceeds 100,000 tons (worth £1,500,000 at present prices) and is steadily expanding. Progressive increase is assured in the demand for rail and tramway products, and in bridge, telephone, and fencing materials. Most of (*b*) and all of (*c*) products would naturally continue to be imported for many years, but infant industries already in existence, such as nail and bolt making and windmill building, would be likely to expand. Also there is a real opportunity for the manufacture of agricultural implements, which at present are imported mainly from America and are often but poorly suited to African conditions.

To sum up, although there is an almost entire absence of demand for iron and steel for the shipbuilding and engineering industries, South Africa consumes every year sufficient of these products to absorb the output of a well-equipped works of moderate size. But would such a works be able to secure orders in the face of outside competition?

A works occupying a good site—at Pretoria, for instance—would enjoy several inherent advantages:

1. All raw material would be obtainable locally from open workings or shallow mines at a very cheap rate. Experimental plants at Pretoria and Vereeniging have proved that excellent pig iron can be cheaply produced from local ore and coke.

2. Administrative and technical ability and skilled labour would have to be somewhat more highly paid than in Britain, but unskilled general labour would be much cheaper. Also the direct burden of local rates and the indirect one of taxation are a mere tithe of what they are in Britain.

3. Coke oven gas if not utilized at the steel works would command a good price, and the by-products, such as sulphate of ammonia, tar, and benzol, could be disposed of at a considerably higher price than in Europe.

4. The absence of cheap water transport, while it will probably debar the industry from all markets except the African ones, is in effect a bonus to local producers. From a central point, such as Pretoria, iron and steel could be supplied to the Rand and a great part of South Africa at a lower transport cost than the imported product could be from the ports.

5. Granted all this, there are the difficulty, expense, and high costs of production inseparable from the starting up of a new works to be considered. To tide over this initial difficulty the Union Government has offered to a properly equipped works, capable of producing 50,000 tons of pig iron and steel—

(*a*) A bounty of 15s. a ton on all pig iron and a further 15s. a ton on all steel produced during the years 1924, 1925, and 1926. From 1927 the bounty would decrease 2s. 6d. a year on a sliding scale, till it disappeared at the end of 1932.

(*b*) A guarantee to give to local works all rail orders for a considerable number of years.

In the background looms the possibility of utilizing South Africa's magnificent waterfalls, the Victoria Falls in Rhodesia, the Hawick and other falls in Natal, and perhaps the Orange River itself, for generating cheap electrical power. Under

this changed order of things the South African steel industry might be able to compete on equal terms in all the world markets. But even if this never comes to pass the Union seems sure to become the industrial area of Africa.

The Beginnings of an African Steel Industry.

Shortly after the War attempts were made by local engineers to start works at Pretoria and Newcastle, and ever since 1912 the Union Steel Corporation has been manufacturing rails, bars, castings, etc., from scrap at their Vereeniging works. For the last three years the output of steel has been—

1921	11,444	South African tons (2,000 lbs.).
1922 (includes a three months' strike) ..	9,854	,, ,, ,,
1923	17,012	,, ,, ,,

This is the only company that has worked continuously. The small measure of success that has hitherto attended these efforts is clearly traceable to two causes —lack of co-operation and insufficient capital. This is so clear that for some time the South African Iron and Steel Corporation of Pretoria has been negotiating with a view to raising a capital of about £2,000,000 with which to set up a works capable of an annual output of 75,000 tons of steel from local ores. Up to the present it has not secured the necessary backing.

It is easy to see why the established steel firms of Britain have hesitated to sponsor the project. Productive capacity has temporarily outrun the world's effective demand, and therefore they would prefer to supply the needs of the Union from their English works. South Africa, on the other hand, feels the urge of industrialism, and is determined to utilize her raw materials as soon as possible. It may not be long before some British steel firm of established reputation will see its way to establishing a manufacturing branch in the Union. Industrial decentralization will come as surely as political decentralization has done, and it will naturally lead to a more equitable distribution of the white population of the Empire. To help to bring this about in a way that will increase the prosperity and happiness of all is one great aim of the first British Empire Exhibition.

A Note on Books.—Readers will find much detail which this brief account has necessarily omitted in the following works: *Coal, Coke, and By-Products*, part ii. (1922); *Statistics* (1923); *Iron Ore*, part ii. (1922), all published, with useful maps and tables, by the Imperial Mineral Resources Bureau, and obtainable from H.M. Stationery Office; C. W. Harrison's useful volume, *Trade Industries, Productions, and Resources of British South Africa* (1923); Professor R. A. Lehfeldt's *National Resources of South Africa* (Longmans, 1922), a critical survey in economics; *The Journal of the South African Institution of Engineers*, vol. xxi., No. 10, 1923, for a detailed account of the works of the Union Steel Corporation; *The South African Journal of Industries*, *passim;* the publications of the South African Government, etc.

CANADA

With regard to Canada the Report of the Imperial Mineral Resources Bureau comes to the conclusion—

"That there are ample supplies of coal in the Dominion, and most of the other materials required by steel makers are to be found in abundance, a fact which affords a strong incentive to search for new and suitable deposits of iron ore."

The coal resources of Canada have been estimated to be equal to 50 per cent. of those of the British Empire and 14 per cent. of those of the world. It is mined in Nova Scotia, New Brunswick, Saskatchewan, Alberta, British Columbia, and the Yukon, but since the principal deposits lie in the eastern and western portions of the Dominion, the industrial provinces of Ontario and Quebec obtain their coal from Pennsylvania, so that almost as much coal is imported as is raised in the Dominion. In 1922, for instance, the coal output was 15,045,286 tons and the imports 14,355,619 tons; of the coal raised in the Dominion, 1,818,582 tons was exported chiefly to the U.S.A. and Newfoundland.

As regards iron ore, although the larger portion of the vast Dominion of Canada has as yet not been thoroughly prospected, sufficient work has been done to demonstrate that large resources of iron ore undoubtedly exist. The total developed ores have been estimated at 300,000,000 tons, but of this 80 per cent. would consist of low-grade ore requiring treatment before being available for the blast furnaces.

Most of the iron ore at present being mined comes from the province of Ontario, 174,687 tons being raised in the northern part of that province in 1919, out of a total of 176,045 tons for the whole Dominion. The ores are mined by the Algoma Steel Corporation, Ltd., operating the Magpie mine, and Moose Mountain, Ltd., operating magnetite in the Sudbury district, where over 100,000,000 tons of magnetite have been proved.

The Magpie mine is situated in the south-east quarter of Township 29, Range XXVI., Algoma district, and is connected by a short branch line with the Michipicoten division of the Algoma Central and Hudson Bay Railway. The composition of the raw ore, according to the analysis of a sample taken by Mr. C. W. Knight, of the Ontario Bureau of Mines, in 1913, is as follows:

Metallic iron	34·30 per cent.
$FeCO_3$	53·20 ,,
FeO	3·50 ,,
Fe_2O_3	8·40 ,,
$CaCO_3$	9·79 ,,
$MgCO_3$	11·57 ,,
$MnCO_3$	4·60 ,,
Insoluble	3·40 ,,

and after being roasted, the analysis of the shipments in 1916 was as follows:

Iron	50·10 per cent.
Silica	9·14 ,,
Sulphur	0·136 ,,
Phosphorus	0·013 ,,
Alumina	1·28 ,,
Lime	7·96 ,,
Magnesia	8·04 ,,
Manganese	2·74 ,,

The Helen mine, also in Algoma, and belonging to the Algoma Steel Company, is now almost exhausted and operations there ceased in 1918. This mine has produced more ore than any in Canada, the shipments for the years 1900 to 1915 amounting to 2,263,522 tons.

The Moose Mountain area is in the district of Sudbury, and comprises about 4 square miles extending north-westerly from Lot 6, Concession III., of Hutton township into the adjoining township of Kitchener, a distance of 4½ miles. It includes the ore bodies of the Moose Mountain mine situated at the village of Sellwood on the Canadian Northern Railway. It has been estimated that for each 100 feet in depth the deposits should yield 38,665,000 tons of siliceous ore, and on a basis of 2·1 tons of ore to 1 ton of concentrates, about 18,500,000 tons of concentrates averaging 65 per cent. iron.

On account of the low iron content, therefore, Canada at present raises only 5 per cent. of her requirements of iron ore, and imports the remainder from Newfoundland and the United States. In fact, in 1922, when the production of pig iron and steel was less than for many years past, no ore was raised in the whole of the Dominion.

In view of the fact that the exportable surplus of ore from the United States of America is diminishing, the Ontario Government has appointed a Committee to investigate the situation with a view to the possible development of iron ore deposits in Ontario.

As early as 1873 an attempt was made to establish an iron and steel industry in Canada; this was by the Steel Company of Canada, at Londonderry, Nova Scotia, who erected two blast furnaces and several melting furnaces and manufactured castings, car wheels, etc. Although Sir William Siemens was associated with this venture it proved a failure, and the next attempt was made in 1899, when the Dominion Iron and Steel Company was established at Sydney, Cape Breton, using Newfoundland iron ores and local coal and coke.

In 1896 a system of bounties was inaugurated for the encouragement of the manufacture of iron and steel from home ores and resulted in the erection of blast furnaces, so that Ontario now has eleven furnaces, and Nova Scotia, the only other province producing pig iron, eight. The principal companies owning these furnaces, with the number of their steel furnaces, is shown below:

	Blast Furnaces.	*Steel Furnaces.*	*Coke Ovens.*
Algoma Steel Corporation ..	4	14	160
Dominion Steel Corporation* ..	6	15	240
Nova Scotia Steel and Coal Co.*	2	5	—
Steel Co. of Canada	2	12	80

* Constituents of the British Empire Steel Corporation.

There are also thirty electric steel furnaces owned by thirteen different companies in the Dominion.

The production of iron ore, pig iron, and steel from before the War to 1922 is given below:

	Coal (*Tons*).	*Iron Ore* (*Tons*).	*Pig Iron* (*Tons*).	*Steel* (*Tons*).	*Imports of Iron Ore Consumed* (*Tons*).
1912	14,512,829	192,753	912,878	853,031	2,019,165
1913	15,012,178	274,673	1,015,118	1,042,503	2,110,828
1914	13,637,529	218,620	705,972	743,352	1,324,326
1915	13,267,023	355,457	825,420	912,755	1,463,488
1916	14,483,395	245,693	1,069,541	1,286,509	1,964,598
1917	14,046,759	192,234	1,085,981	1,562,289	2,084,231
1918	14,977,926	188,936	1,106,564	1,694,977	2,146,995
1919	13,681,218	176,045	862,866	927,641	1,674,194
1920	16,631,954	114,130	998,814	1,109,922	1,957,738
1921	14,492,418*	—	615,765	669,548	661,168
1922	15,045,286*	—	401,994	481,137	887,360
1923 (provisional)	—	—	822,633	884,760	—

The effect of the war stimulus to the industry is plainly evident, but there has been no permanent advance as far as pig iron and steel are concerned, for in no post-war year has production much exceeded that of 1913. There has, however, been a growth in the manufacture of products derived from iron and steel. The output of finished steel in the last few years has been:

	1918 (*Tons*).	1919 (*Tons*).	1920 (*Tons*).	1921 (*Tons*).	1922 (*Tons*).
Rails	145,309	282,415	227,967	266,170	124,728
Structural shapes and wire rods	141,978	163,489	246,582	76,315	117,775
Plates and sheets, nail plate, merchant bars, tinplate bars, etc.	714,021	297,095	457,357	169,423	188,394

The following table shows the imports of iron and steel into Canada for the fiscal years ending March 31, 1921, 1922, and 1923, showing for the latter two years how much came from the United Kingdom and the United States.

In 1913, out of the total imports into Canada, 11 per cent. came from the United Kingdom, 87 per cent. from the United States, and 2 per cent. from other countries; in the year ending March 31, 1923, 9 per cent. came from the United Kingdom, 90 per cent. from the United States, and 1 per cent. from other countries. The imports of tinplates in 1923 are exceptionally interesting, for the victory of the British tinplate over the American was only obtained after a long struggle.

In a few cases imports are free—as, for example, ferro-manganese and spiegeleisen, containing over 15 per cent. manganese; boiler plates not less than 30 inches in width and ¼ inch thick for boilers under the regulation of the Ministry of

* Includes waste coal and slack previously excluded.

Customs; wrought or seamless iron or steel tubes for boilers for same; rolled iron or steel hoops, etc., No. 14 inch gauge and thinner for use in importers' own factories for manufacture of galvanized iron or steel hoops, band, scroll, strips or sheet; also No. 10 gauge and thinner imported by manufacturers of cold rolled iron or steel; Swedish rolled iron and rolled steel nail rods under ½ inch for manufacture of horseshoe nails. In most other cases the duty is either ad valorem, varying from 5 per cent. to 22½ per cent. in the British preferential tariff, with increases of 50 per cent. to 66 per cent. on the general tariff or a specific duty—*e.g.*, 2 dollars per ton on beams, channels, etc., which is also 50 to 66 per cent. higher in the case of the general than in the case of the British tariff.

	Total Imports.			*Imported from United Kingdom.*		*Imported from United States.*	
	1921 (*Tons*).	1922 (*Tons*).	1923 (*Tons*).	1922 (*Tons*).	1923 (*Tons*).	1922 (*Tons*).	1923 (*Tons*).
Pig iron	56,350	18,416	64,960	438	34,436	17,084	29,762
Ferro-silicon and ferro-manganese	9,029	1,539	4,566	903	3,508	514	1,056
Band and hoop ..	133,504	31,746	58,304	2,441	4,778	29,167	53,136
Plates and sheets:							
Boiler plate ..	13,045	3,022	7,225	—	283	3,022	6,942
Canada plates	9,873	7,709	15,371	949	5,994	6,760	9,377
Tinned plates	59,289	37,111	53,417	13,392	35,029	23,719	18,388
Galvanized ..	25,459	13,680	35,999	956	14,811	12,725	21,185
Skelp for pipe	102,903	50,584	92,061	—	108	50,584	91,953
Other plates and sheets ..	116,525	41,928	103,982	755	8,158	41,075	95,731
Rods	29,511	17,802	21,176	58	326	16,786	18,143
Wire (barbed, fencing)	20,928	8,307	5,272	—	6	8,302	5,266
	(£)	(£)	(£)	(£)	(£)	(£)	(£)
Other pigs, ingots, blooms, billets	869,805	405,359	537,839	4,075	6,194	396,469	505,652
Castings and forgings	6,790,520	3,787,460	3,304,595	661,214	258,102	3,124,351	3,046,274
Bars and rails ..	6,776,714	2,601,282	5,288,881	15,376	225,032	2,552,492	5,022,452
Structural iron ..	13,137,023	2,205,574	5,587,987	3,116	80,152	2,201,773	5,496,861
Tubes, pipes, and fittings ..	6,226,128	2,166,020	2,656,931	105,474	182,898	2,028,147	2,450,622
Other wire ..	6,084,126	2,189,298	2,702,047	668,122	997,086	502,833	1,695,230
Chains	1,304,654	464,288	541,539	99,307	143,211	361,648	398,200

According to the Report of the Department of Overseas Trade for 1923, the capital invested in the iron and steel industry in Canada amounted in 1920 to nearly 650,000,000 dollars and the annual value of the products was 640,000,000 dollars. Of shares and bonds of a par value of 392,000,000 dollars outstanding at December 31, 1920, Canadians held 182,800,000 dollars, British investors 17,600,000 dollars, and United States investors 149,500,000 dollars, the remainder being made up of investments from other countries. The distribution of capital and value of products was as follows:

Classification.	*Capital* ($).	*Value of Products* ($).
Blast furnaces and steel mills	119,761,718	138,882,823
Foundries and machine shops	68,346,628	76,766,903
Iron and steel fabrication	12,355,869	14,318,685
Boilers and engines	32,662,552	22,614,951
Agricultural implements	110,868,713	50,301,302
Machinery	52,066,936	40,535,474
Motors and cycles	72,252,428	123,148,206
Cars and car parts	66,951,866	60,359,520
Heating and ventilating	28,910,344	23,125,680
Wire and wire goods	18,339,020	30,254,349
Sheet metal products	27,589,735	37,369,576
Hardware and tools	32,798,513	22,556,316
Total	642,904,322	640,233,785

Attention has more recently been given to the possibility of establishing an iron industry in British Columbia, and the Geological Survey of Canada has undertaken to investigate the iron ore resources of that province, for it has long been known that many bodies of iron ore exist on or close to the mainland coast and the shores of Vancouver Island, and it has been repeatedly asserted that fuel and flux are also available at various places along the sea-coast of the province.

Considerable progress has already been made in the examination of the known ore occurrences, but it is expected that by the end of 1924 sufficient information will have been collected to indicate definitely whether or not there exists a reserve of iron ore sufficiently large to warrant the establishment of a blast furnace plant.*

Although the bulk of the iron ore used in the Dominion is imported, about one-third comes from the deposits in Newfoundland belonging to the Dominion Steel Corporation and Nova Scotia Steel and Coal Company, constituents of the British Empire Steel Corporation, which thus controls the largest single deposit of iron ore in the world.

NEWFOUNDLAND.

The iron ore deposits of Newfoundland have been estimated to amount to about 3,500 million tons, a quantity sufficient to meet the whole world's demands for a period of twenty years; the deposits are also of almost every known variety of iron ore. There are deposits of hematite, chromite, cupriferous pyrites containing 30 to 35 per cent. of iron, titaniferous magnetite, limonite, and other forms, but the only important development is that of the Wabana mines on Great Bell Island. The hematite deposits were first worked in 1895, but the large deposits of titaniferous magnetite, though containing 65 per cent. of iron and no sulphur and phosphorus, are not mined, because they contain from 4 to 16 per cent. of titanium.

The mines are excellently equipped in every way, and should be able to produce ore cheaply. The ores are transported direct from the mining levels

* From an article prepared by Mr. G. A. Young of Canadian Geology Survey.

to a large hopper from which they run direct into the hold of the steamers at the rate of 2,000 tons per hour. Steamers up to 13,000 tons can lie alongside the wharf, and, with the exception of a few weeks in winter, shipping is continued all the year round.*

The distances of the Wabana mines from the principal markets for ore are as follows:

To Sydney, Nova Scotia	415 miles.
„ New York	1,110 „
„ Philadelphia	1,240 „
„ Glasgow	1,900 „
„ Rotterdam	2,300 „
„ Middlesbrough	2,350 „

Although the ore is a hematite, it is too high in phosphorus to be smelted by the acid process—it is, therefore, unsuitable for most of the blast furnaces in the pig-iron producing districts on the west coast of Britain (*i.e.*, Scotland, Cumberland, Lancashire, and South Wales). On the other hand, it is an additional 450 miles to Middlesbrough, for whose furnaces the ore is suitable. The maximum export of the ore in any one year to Great Britain has, therefore, been no more than 115,840 tons in the year ending June 30, 1914. A certain amount of the ore was exported to Germany and Holland before the War, and Germany has also made purchases of Wabana ore since the War on account of her difficulties over Lorraine, but of the total exports from the Wabana mines of 16,758,000 tons to the end of 1919, nearly 70 per cent. went to Nova Scotia.

It is considered doubtful whether, even with reduced freights, Newfoundland ore could be profitably utilized in Great Britain, but it has been suggested that it might be possible for pig iron and semi-finished steel to be manufactured at Sydney and shipped to Great Britain in competition with the Continental material which was imported in such quantities before the War and which is now being imported again.

An agreement has been come to between the Newfoundland Government and the British Empire Steel Corporation which was confirmed by the House of Assembly in 1921 and provided for, *inter alia*—†

1. An export tax of 25 cents per ton for twenty years from January 1, 1921, on all ore shipped to Nova Scotia.

2. Free exportation to all countries other than the Dominion of Canada. The companies, however, must spend 3 million dollars during the next five years in improvements and developments of their plants, must give notice before January 1, 1926, of their intention to erect a smelting plant capable of producing 100,000 tons of pig iron, and have such plant erected before January 1, 1928, otherwise the Government will have the right to collect a maximum duty of 10 cents per ton on ore exported to parts of the world other than the province of Nova Scotia.

* *Report of I.M.R.B.*, Part III., British America, p. 102.
† *Ibid.*, pp. 111 and 112.

3. In any year that the shipments to Nova Scotia amount to a million tons, there will be no tax on the ore shipped to any other place in Canada. When shipments fall below that mark, however, the tax of 25 cents will apply to other places.

4. All materials for the construction of and for use in connection with the operation of the smelting plant are to be admitted free of duty.

5. The companies are exempted from Business Profits Tax, War Income Tax, and any future tax of a similar character. They are also exempted from municipal taxation for ten years, and thereafter are not to be called upon to pay more than 10,000 dollars annually.

6. The Government may grant the Dominion Iron and Steel Company the Rocky River (Colinet) water powers, and the latter will pay 25 cents per horse-power developed annually.

7. The companies must operate their smelting plant to full capacity. Failure to do so will mean a 10 cent per ton tax on ore shipped elsewhere than to Canada.

8. The ore tax will be payable quarterly on the 15th of January, April, July, and October in each year.

9. The companies must provide a sufficient quantity of coal to meet the requirements of the railway, including steamers and docks, the requirements of the Reid Company generally, and the domestic requirements of Newfoundland, at f.o.b. prices per ton current from time to time on coal of similar quality sold for shipment to Nova Scotia ports. The companies also engage to establish a coal depôt in Newfoundland, if the Government shall so request.

10. The companies agree to abide by any labour dispute settlement laws of this country.

11. If the Government so request the companies shall build houses on Bell Island for their employees, on a twenty years purchase plan.

CHAPTER IV

*PIG IRON**

ALTHOUGH many attempts have been made, and are still being made, to produce steel direct from iron ore in one direct process, they have not yet proved successful on a commercial scale, and practically all the steel produced has first to go through the stage when it is known as pig iron. Pig iron is made in the blast furnace, a very complicated apparatus which has a long history during which many improvements have been made. Professor Turner takes the following account of a blast furnace in 1686 from Dr. Plot's *Natural History of Staffordshire*, p. 161:

" When they have gotten their ore before it is fit for the furnace, they burn or calcine it upon the ground, with small charcoal, wood or seacoal, to make it break into small pieces, which will be done in three days, and this they call annealing it or firing it for the furnace; and then they bring the ore to the furnace thus prepared, and throw it in with the charcoal in baskets—*i.e.*, a basket of ore and then

* Grateful acknowledgments are due to Mr. J. J. Burton for help in compiling this chapter.

a basket of coal. Two vast pairs of bellows are placed behind the furnace and compressed alternately by a large wheel turned by water, the fire is made so intense that after three days the metal will begin to run; still after increasing until at length in fourteen nights' time they can run a sow and pigs once in twelve hours, which they do in a bed of sand before the mouth of the furnace.

" . . . The hearth of the furnace into which the ore and the coal fall is ordinarily built square, the sides descending obliquely and drawing near to one another like the hopper of a mill; where these oblique walls terminate, which they call the boshes, there are set four other stones, but these are commonly set perpendicular, and reach to the bottom stone, making the perpendicular stone that receives the metal."

A modern blast furnace is more or less cylindrical in shape and usually 85 to 95 feet in height; at its widest part its diameter would be 20 to 22 or even up to 25 feet. Iron ore and coke and limestone are charged alternately into the top by mechanical devices in proportions determined chiefly by the iron and silica contents of the ore. Great attention is paid to the mechanical and physical conditions of the ore and coke; it is desirable, but not always attainable, that ores should be reduced to sizes that will pass through a 3 or 4 inch ring with few smalls, while the coke should be strong, but not of great density, and as low as possible in ash and sulphur. Oxygen must be introduced into the furnace for the combustion of the fuel, and the air is nearly always heated in " stoves " to about 1,150° to 1,250° F.; there are usually four stoves per furnace, the outer shell of which is 60 to 100 feet in height and 20 to 22 feet in diameter.

The manufacture of pig iron is a " continuous process "—that is, the action of the blast furnace must not cease day and night, Sundays and weekdays. The action of starting up a furnace, either for the first time, or after it has been out of action for some time, is called " blowing in," and it is usually a matter of several months before a furnace reaches its maximum output. Ironmasters are, therefore, loth, except for relining or repair, to " blow out " a furnace; they prefer to " damp down "—that is, to charge in a quantity of coke and shut off all access of air. By this means the heat may be retained for many weeks, and if all goes well smelting can be resumed in about two days, but there are so many complications that the greatest care must be taken and the blast furnace manager has an anxious time. It used to be no uncommon thing for a furnace to last ten to fifteen years or even longer before requiring relining, but with more rapid driving the " life " of a furnace has gradually been reduced. It is understood that some of the American furnaces giving big outputs require to be relined every three years, but the average life of a British furnace is from five to seven years. A blast furnace used to be " tapped " only twice in twenty-four hours, but this was gradually improved to every eight, then six, and finally every four hours. The time spent in opening and blocking the tapping hole has been saved by the invention of the " tapping gun." It takes about sixteen hours for the material to work down from the top to the bottom of the furnace. The molten iron, when not run direct into a ladle for delivery in a molten condition to the steel works, is run into specially prepared channels in sand and allowed to solidify; the main channels are known as " sows "

and the shorter ones on each side as "pigs," from the supposed resemblance to sows feeding a litter of pigs.

In America, instead of being run into sand moulds the pig iron is now very largely cast by a pig-casting machine for which the following advantages are claimed:* that it enables the molten metal to be immediately removed from the vicinity of the blast furnace; the iron is free from sand; very little manual labour is required, with a consequent saving in labour charges; the size of the pigs is uniform, etc. The pig-casting machine has not, however, been introduced into many works in this country, though in the U.S.A. in 1922 out of 9,250,284 tons not delivered molten, 7,061,301 tons were machine cast.

Except for a small tonnage of "direct castings" the pig iron produced is either steel-making pig iron for subsequent conversion into steel, forge pig iron for conversion into wrought iron, or foundry iron for the manufacture of iron castings.

Foundry Iron.

Castings are much more easily and cheaply produced than forgings, so that the latter are only employed where special requirements of strength or ductility render their adoption necessary; while, as compared with steel castings, the advantages of cast iron for ordinary uses include not only the cheapness of the original material, but also the diminished cost in preparation of the moulds, the smaller loss in casting, and in the saving of expense and time required for annealing, which is necessary with steel but not for cast iron.† Iron castings can thus be prepared to meet a pressing emergency, while their fine surfaces, sharp edges, and pleasing appearance recommend them for general use. It is probable, therefore, that while the greater strength of steel will lead to its extended application in the future, this will not result in the exclusion of cast iron. The two great desiderata in foundry irons are strength and fluidity. To obtain the former quality, hematite pig is often added to a foundry iron, while a high silicon content aids fluidity and also enables a higher proportion of scrap to be used in the cupola. In general foundry work, therefore, it is common to mix the irons of different localities, so that each kind of iron used supplies what is lacking in the other.

In America there is still a substantial amount of charcoal pig iron produced (*e.g.*, 323,400 tons in 1920, and 224,700 tons in 1922), but in Great Britain, as we have already seen, there is only one furnace producing charcoal pig iron. The following is an analysis of the well-known charcoal cold blast hematite pig iron:

	Graphitic Carbon.	*Combined Carbon.*	*Silicon.*	*Sulphur.*	*Phosphorus.*	*Manganese.*
Grey No. 1.. ..	3·60	0·75	0·85	0·014	0·065	0·295
,, No. 2.. ..	3·375	0·825	0·633	0·016	0·067	0·275
,, No. 3.. ..	3·344	0·720	0·529	0·02	0·067	0·254
Mottled (soft) ..	2·516	1·40	0·47[illegible]	0·023	0·068	0·206
White	Trace	3·616	0·358	0·026	0·067	0·055

Again, although most of the blast furnaces in this country now employ the hot blast, there are still some firms who can produce cold blast pig iron. A much

* A. K. Reese, *Journal of the Iron and Steel Institute*, vol. cvi., No. 2, 1922.

† T. Turner, *The Metallurgy of Iron*, p. 286.

purer iron is produced by the cold than with the hot blast, and it is therefore used for the manufacture of the best Yorkshire wrought irons, while in the foundry it is used for the production of castings such as engine cylinders, etc., where great soundness and tenacity are required, and in the manufacture of iron castings subjected to heavy shocks and strains.

Cold blast pig iron is classified into the following grades:

No. 1. Foundry quality (used for making toothed wheels for machinery, etc., and for castings which experience great heat or variation of temperature).

No. 2. Foundry quality.

No. 3. Foundry and forges (used for the best castings in foundries and in forges for producing best sheets for deep stamping, etc.).

No. 4. Forge (for strong castings for locomotive, marine, and stationary engines).

No. 5. Mottled.

No. 6. White.

Perhaps the best known cold blast pig iron is that of the Lowmoor iron works, the analysis of which is as follows:

	Graphitic Carbon.	*Combined Carbon.*	*Silicon.*	*Sulphur.*	*Phosphorus.*	*Manganese.*
No. 1 (foundry) ..	2·94	0·59	1·3 to 1·5	0·042 to 0·07	0·35 to 0·45	1·20 to 0·90
No. 2 " ..	2·96	0·56				
No. 3 (forge and foundry) ..	2·85 to 2·94	0·65 to 0·7	1·2 " 1·5	0·02 to 0·08		
No. 4 (forge) ..	2·7 " 2·8	0·5 " 0·75	0·8 " 1·2	0·04 " 0·10	0·35 " 0·50	0·70 " 0·95
No. 5 (grey) ..	2·6 " 2·7	0·65 " 0·75	0·5 " 1·1	0·15 " 0·07	0·35 " 0·50	0·65 " 0·85
No. 6 (hard) ..	2·0 " 2·4	0·8	0·45 " 0·70	0·15 " 0·12	0·35 " 0·50	0·70 " 0·80
White and mottled ..	Nil	2·8 to 3·0	0·45 " 0·50	0·17 " 0·20	0·35 " 0·50	0·40 " 0·25

Hot blast pig irons are also graded according to size and number of the crystals, the classification now in general use being No. 1, No. 2, No. 3, No. 4 (foundry), No. 4 (forge), mottled and white. No. 3 is the quality most universally used, No. 1 being largely used for mixing purposes; probably 60 to 70 per cent. of the foundry iron produced is either No. 3 or No. 1. No. 4 (foundry) is the lowest grade and is used for heavy work; " mottled " and " white " are low grades, " white " making chilled iron for hard wear and tear, but cannot be machined.

Tests.

The tests applied to foundry iron are both mechanical and chemical; the pig iron is usually re-melted and cast in green sand and into bars 12 inches long and ½ inch square and tested for shrinkage, transverse strength, grain of fracture, resistance to impact, fluidity, hardness, etc.; the tests are described in most works on foundry practice.

Foundry iron is produced in the Midlands, on the North-East Coast, in Scotland, and to some extent in Sheffield. The quantity produced on the West Coast,

Lincolnshire, and South Wales is negligible. The customs returns do not differentiate between forge and foundry pig irons, but the export to various countries of these two kinds together in 1913 and 1923 was as follows:

	1913 (*Tons*).	1923 (*Tons*).
British India	8,485	9,012
Australia	31,769	7,567
Canada	21,779	12,208
Other British Possessions	16,212	18,311
Total British Possessions	78,245	47,098
Sweden	85,522	26,993
Norway	25,766	7,142
Denmark	33,284	18,844
Germany	103,356	63,852
Netherlands	29,406	16,243
Belgium	37,824	31,107
France	62,492	16,597
Italy	91,814	29,118
Japan	76,211	5,568
U.S.A.	7,302	168,158
Other foreign countries	69,659	28,917
Total foreign countries	622,636	412,539
Total	700,881	459,637

Forge Pig Iron.

Forge iron requires to be as low in silicon as possible and not higher than 1 to 1½ per cent., although in the case of Lincolnshire, where the iron ore is too limey, a certain amount of silicon has to be added. The total production of forge iron in the last few years has been: 1920, 605,000 tons; 1921, 239,700 tons; 1922, 277,600 tons; 1923, 417,200 tons. In 1920 the total included 215,100 tons from Derbyshire, Leicestershire, Nottinghamshire and Northamptonshire, 138,200 tons from Staffordshire, Shropshire, Worcestershire and Warwickshire; 131,800 tons from the North-East Coast, and 55,500 tons from Scotland.

Steel-making Iron.

Steel-making iron may be either hematite (acid) or basic. To be suitable for the acid process of steel-making, the pig iron should be as low as possible in sulphur and phosphorus, but high in silicon, which assists in maintaining a high temperature in the steel furnace. For the basic process the pig iron requires to be low in sulphur and silicon, but high in phosphorus; the presence of sulphur in the iron makes for brittleness. The phosphorus is eliminated in the process of basic steel making, and combines with the lime to form the valuable fertilizer known as basic slag.

In specifying for acid pig iron buyers usually insist that the sulphur and phosphorus content shall not exceed a certain maximum, usually 0·64 per cent.,

while for basic iron purchasers usually specify for not more than a certain maximum of sulphur and silicon and a minimum of manganese.

Out of a total production of 8,034,700 tons of pig iron produced in 1920, 2,941,900 tons were hematite and 2,661,700 tons basic. Perhaps a third of the hematite produced would be used for foundry purposes and the remainder, except for 187,700 tons exported, sent to steel works. Practically all the basic iron would go to the steel works. About one-third of the pig iron sent to steel works was sent in a molten condition. As we have seen (Chapter II.), the only home ores suitable for acid pig-iron making are in Lancashire and Cumberland. Hematite pig iron is, therefore, made only on the West Coast both from home and imported ores, and in South Wales, the North-East Coast, and Scotland, where the non-phosphoric ores of Spain can be imported. In 1920 the production of these districts was—

North-East Coast	996,700 tons.	South Wales and Monmouth ..	623,600 tons
West Coast	909,800 „	Scotland	411,800 „

Basic pig iron is produced in more or less quantities in all the pig-iron producing districts, although naturally the quantities are small in Scotland, South Wales, and the West Coast, the biggest production being on the North-East Coast (983,300 tons in 1920) and the second place being taken by Lincolnshire (541,000 tons).

Other products of the blast furnace are the ferro-alloys—ferro-manganese, spiegeleisen, and ferro-silicon. In the manufacture of ordinary mild steel about 0·5 per cent. of ferro-manganese is added in the ladle to improve the working qualities. Ferro-silicon is largely used in foundry practice. There are seven firms producing ferro-alloys in blast furnaces in Great Britain, and these manufacture not only for the home market, but also for export. The production of ferro-manganese, spiegeleisen, and ferro-silicon in the last few years has been as follows:

	Total (*Tons*).	*Ferro-Manganese* (*Tons*).	*Spiegeleisen* (*Tons*).	*Ferro-Silicon* (*Tons*).
1920 ..	244,000	183,300	51,200	7,700
1921 ..	52,100	36,200	15,900	—
1922 ..	227,600	190,400	36,100	1,100
1923 ..	275,000	256,100	10,500	8,400

The exports of ferro-manganese and spiegeleisen are taken mostly by the U.S.A. and Belgium, the exports amounting in the last few years to—

	1920 (*Tons*).	1921 (*Tons*).	1922 (*Tons*).	1923 (*Tons*).
Belgium	38,570	9,076	12,697	21,456
U.S.A.	54,852	12,926	108,219	105,601

Manganese ore for the manufacture of ferro-manganese is found in India, the Caucasus, and Brazil, and spiegeleisen is made from the manganiferous iron ore from Spain. Before the War nearly half of our supplies of manganese ore

came from Russia, the bulk of the Brazilian supplies going to the United States. During and since the War larger proportions have been drawn from India. The seven firms producing ferro-alloys have nineteen furnaces devoted to their production, of which in normal times twelve would be in operation, the remaining seven being needed as stand-bys, since, on account of the destructive nature of the alloys, the furnaces have much shorter lives than blast furnaces producing ordinary pig iron.

When steel works are situated near the blast furnaces the pig iron is usually delivered molten to the steel furnaces, but where steel works do not possess their own blast furnaces, or where these are at a distance, the pig iron must be delivered cold and consequently more fuel is consumed in re-melting. On the Continent the Bessemer process has been developed and is largely used, but in Great Britain about 90 per cent. of the steel produced is made in the " open-hearth " furnace, the operations of which are under greater control, samples being taken at frequent intervals for physical and chemical tests. An open-hearth furnace is a brick chamber usually about 15 feet wide and twice as deep, arched, with a roof from 9 to 12 inches thick. Below the furnace, at each end, are two " checker " chambers, one for heating the air before it is admitted to the furnace and the other for gas. When heating the furnace, air and gas are admitted through the ports and unite in combustion over the hearth which contains the charge of pig iron and scrap to be melted.

At the end of 1922 there were 695 open-hearth furnaces in Great Britain, of which the total capacity was about 33,000 tons per heat—*i.e.*, an average per heat of nearly 50 tons. Eighteen of the furnaces are of 10 tons capacity or under, while 20 are of 100 tons or more, but the majority of the furnaces (381 to be exact) are between 40 and 60 tons. The molten iron from the blast furnace is stored in a " mixer " usually capable of containing 400 tons. An active mixer not only acts as a receptacle, but also as a purifier, removing 60 per cent. of the silicon, 50 per cent. of the sulphur, and 40 to 50 per cent. of the manganese, but no carbon or phosphorus is lost. In all modern plants the pig iron is charged by a mechanical charging apparatus, and whether molten or cold pig iron is used a proportion of scrap is also included; a common practice is to charge 50 per cent. pig iron and 50 per cent. scrap. A furnace is tapped about every twelve to thirteen hours—*i.e.*, eleven to twelve heats per week are obtained, the furnaces being cold at the week-end; the output of a 60-ton furnace, for instance, is thus 660 to 720 tons per week. The molten steel, to which limestone, lime, or Gellivare ore is added in the bath for purifying purposes, is run off into ladles, then " teemed " into ingot moulds, the capacity of which varies in weight from 15 cwts or less to 50 tons or more. After the ingot is " stripped " it is placed in the " soaking pit " to retain its heat until sent to the " cogging mill," where it is passed backwards and forwards between two heavy rollers until reduced to the thickness required for the tinplate or sheet bars, or the billets, blooms, or slabs into which it is cut to form the starting-point for the various steel products which are discussed in the following chapters.

The following are some typical analyses of pig iron as communicated by the districts concerned:

	Graphitic Carbon.	Combined Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
West Coast hematite:						
No. 1	3·75	0·30	2·60	0·02	0·045	0·50
No. 2	3·50	0·46	2·40	0·03	0·045	0·50
No. 3	3·25	0·54	2·10	0·04	0·045	0·50
No. 4	2·80	1·00	1·65	0·10	0·045	0·50
No. 5	2·40	1·60	1·20	0·20	0·045	0·50
Mottled	1·60	1·95	0·90	0·25	0·045	0·20
White	Trace	3·25	0·65	0·30	0·045	0·10
East Coast hematite:						
No. 1	3·725	0·15	2·75	0·03	0·05	1·00
No. 2	3·525	0·25	2·50	0·04	0·05	1·00
No. 3	3·30	0·40	2·25	0·06	0·05	1·00
No. 4	3·10	0·60	1·50	0·10	0·05	1·00
No. 5	2·450	1·55	1·00	0·20	0·05	0·75
Mottled	1·500	2·05	0·75	0·25	0·05	0·50
White	Trace	3·15	0·65	0·30	0·05	0·50
Scotch hematite:						
No. 1	3·25	0·30	2·75	0·02	0·05	1·50
No. 3	2·90	0·40	2·0 to 2·5	0·04	0·05	1·50
Mottled	2·00	1·00	1·20	0·20	0·05	1·50
White	Trace	2·50	0·75	0·30	0·05	1·50
Welsh hematite:						
No. 1	3·75	0·30	2·0 to 3·00	0·04 (max.)	0·06 (max.)	0·8 to 1·2
No. 2	3·50	0·32	1·75 ,, 2·25	0·04 to 0·055	0·06 ,,	0·8 ,, 1·2
No. 3	3·20	0·42	1·50 ,, 1·85	0·045 ,, 0·065	0·06 ,,	0·7 ,, 1·0
No. 4	2·52	0·90	0·95 ,, 1·40	0·080 ,, 1·0	0·06 ,,	0·6 ,, 0·9
Mottled	1·00	1·90	0·60 ,, 1·00	0·090 ,, 0·12	0·06 ,,	0·4 ,, 0·7
White	0·20	2·88	0·50 ,, 0·75	0·10 ,, 0·14	0·06 ,,	0·3 ,, 0·5
Lincolnshire:						
No. 1	3·17	0·16	2·69	0·031	1·12	1·86
No. 2	2·94	0·37	2·46	0·035	1·20	1·78
No. 3	2·72	0·53	2·30	0·043	1·23	1·47
No. 4	2·30	0·70	1·82	0·044	1·31	1·41
No. 5 (forge) ..	2·89	1·15	1·53	0·058	1·28	1·39
No. 5	0·55	2·91	0·94	0·078	1·29	1·22
Northamptonshire:						
No. 3 (foundry) ..	3·25	0·06	3·00	0·02	1·60	0·35
No. 4 (forge) ..	3·10	0·15	2·00	0·05	1·60	0·30
South Staffordshire:						
All Mine No. 4 ..	2·50	0·50	1·50 to 1·75	0·06 to 0·08	0·06 to 0·070	0·70 to 0·75
Cold Blast Mine (iron):						
No. 1	3·07	0·35	1·48	0·03	0·43	0·96
No. 2	3·04	0·35	1·27	0·04	0·34	0·80
No. 3	3·12	0·40	1·16	0·05	0·44	0·94
No. 4	3·03	0·45	0·83	0·04	0·31	0·27
No. 5	2·81	0·50	0·57	0·06	0·29	0·13
Scotland:						
Scotch Foundry No. 1	3·25	0·25	3·20	0·02	0·70	1·00
,, ,, No. 3	2·90	0·35	2·75	0·03	0·70	1·00

CHAPTER V

*WROUGHT IRON**

HISTORICAL.

Two technical discoveries stand out in the early history of the wrought iron industry. The first is the invention of Cort in 1784 of the system of "dry puddling." The second is the introduction of "pig boiling" in 1830 by Joseph Hall, of Tipton, Staffordshire—the system of puddling which has remained substantially unaltered up to the present day. The direct production of wrought iron from the ore had been practised for centuries in India, Spain, Sweden, Germany, and the Sussex Weald. The achievements of this early period, of which the Delhi column and the numerous examples of decorative ironwork in English churches form striking examples, are a testimonial alike to the skill and to the culture of those responsible. The patent records of the nineteenth century abound with attempts to reintroduce this method of making wrought iron, and it is conceivable that they will continue to be made as long as iron and steel are produced. But since the total output by these methods is relatively insignificant, it is not proposed to refer to them as being of any more than great historical interest.

In Cort's system white iron was worked on a sand-bottomed reverberatory furnace, and the impurities removed by atmospheric oxidation. The process was extremely wasteful, and was useless without a refinery. Of far greater importance was the introduction of groove rolls, which is attributed to Cort about 1793. Hall's process differed essentially by the employment of iron oxides to remove the impurities, substituting slag reactions for atmospheric oxidation. As such it can be justly regarded as the parent of all open-hearth methods for the purification of pig iron. It allowed the use of grey iron in place of white, obviated the necessity for a refinery, and made wrought iron production a commercial proposition.

According to Griffith's *Survey of the Iron Trade* (1875), the average price of marked bars at Liverpool between 1806 and 1829 was £11 9s. 6d. per ton. In 1830 it stood at £7, and the average for 1830 to 1854 was £7 10s. 6d. per ton.

It may be of interest to note that in 1920 the price of marked bars stood at £33 10s. per ton. To-day they are rather less than half this figure. Staffordshire cannot claim to be the pioneer centre of wrought-iron production in this country. For this honour pride of place must be given to Shropshire, to South Wales, and to Yorkshire. But Staffordshire can claim to be the greatest centre of iron-making during the nineteenth century.

* Contributed by the Council of British Wrought Iron Associations (Secretary, H. S. Knowles, Atlantic Chambers, Brazennose Street, Manchester), who desire to acknowledge the valuable services rendered by Lieut.-Col. J. S. Trinham in compiling it.

At Coalbrookdale and Lilleshall a reputation was established before the close of the eighteenth century, built largely upon the very high quality of pig iron which it was possible to make from the local ironstones. In the neighbourhood of Bradford, it is reported, iron nails were made at Kirkstall Forge in the sixteenth century. At Bowling and Lowmoor the ironworks which were subsequently to become so well known were established in 1788 and 1791 respectively.

But it was in the neighbourhood of Stourbridge that the most rapid development took place, due mainly to the efforts of a Mr. James Foster. Among other achievements this gentleman, as chief proprietor, was responsible for the management of Messrs. John Bradley's ironworks at Stourbridge, and for the establishment, in partnership with others, of the famous Chillington ironworks, dismantled forty years ago, and Messrs. John Bagnall's at Wednesbury. To him also is attributed the inauguration of the quarterly exchange days, and the amalgamation of the interests of Shropshire and Staffordshire in the iron trade, by the importation of Shropshire pig for the manufacture of his famous S. C. Crown brand of iron. About this time, too, the Cradley and Netherton districts were the seat of the nail, chain, and anchor trade, and a great impetus was given to wrought iron production in South Staffordshire by Mr. Noah Hingley (founder of the present firm of N. Hingley and Sons, Ltd.), who was the means of introducing the manufacture of large cables into the Midlands.

Meantime in Scotland and in North Staffordshire, where the local clay-band ironstones provided just that raw material which could be smelted into the ideal forge pig iron, a parallel development was taking place.

From very early times a refined iron had been made in the West Highlands of Scotland, where ample supplies of wood for the manufacture of charcoal were available. The modern Scotch iron trade dates from the inauguration of the Carron Company in 1760 by Dr. Roebuck and Samuel Garbett, two English gentlemen, both from the Midlands. Wrought iron was at first produced at Carron in bloomeries from ore and charcoal, and subsequently hammered out by hammers worked by water power. A few years later the Carron Company purchased Cramond Mills for the rolling of their iron, the principal manufacture being nail strip. Puddling furnaces were at work in the early part of the nineteenth century at a number of Scottish blast furnaces, amongst these being Muirkirk.

In North Staffordshire, Messrs. Robert Heath and Sons commenced ironmaking at Kidsgrove about 1820, where the firm already owned extensive collieries and ironstone mines.

During the nineteenth century, development continued until 1872, in which year a general stocktaking of our iron and steel resources appears to have been attempted for the first time. There were in this year 8,115 puddling furnaces in commission in England, with a production of about 2,500,000 tons of iron per annum. The high-water mark of wrought-iron production was not actually reached until 1882, in which year 2,841,534 tons of puddled bars were produced. By 1894 the output had fallen to half this figure and the production according to districts was as follows:

	Puddled Bar (Tons).
North Staffordshire	136,914
South Staffordshire and Worcestershire	389,013
Yorkshire	122,319
Lancashire	145,126
Scotland	195,987
Other districts	349,703
Total	1,339,062

During the next decade the advent of cheap steel continued, but engineers were gradually learning by costly experience that steel could not do everything of which wrought iron was capable, and for a number of years prior to the War the demand for wrought iron had been slightly on the increase. War conditions and the tremendous output of steel for munitions give a false impression of the wrought-iron industry. But post-war years find the iron trade with a fairly steady demand, and with wrought iron holding an assured position in the field of engineering materials. In the six districts where the trade is centred—viz.: (1) South Staffordshire, (2) Scotland (Lanarkshire), (3) South Yorkshire, (4) Lancashire, (5) North Staffordshire, (6) Nottinghamshire and Derbyshire—iron-makers look forward with confidence to a continuance of this demand in the future.

The Manufacture of Wrought Iron.

The manufacture of bar iron may consist of three, and always comprises two, processes:

1. The puddling process.
2. Further treatment of the puddled blooms, slabs, or bars in the forge.
3. The mill re-heating and final rolling.

In the manufacture of the commoner qualities of iron the second of these processes is omitted. It has been established by numerous tests and the experience of many years that virgin wrought iron can be improved by successive workings up to the fifth or sixth working, after which it rapidly deteriorates. The metallurgical results of the first few workings are a more complete expulsion of the slag, a greater chemical purity, and a more stable crystalline structure. The second stage of manufacture indicated above is, therefore, employed in the production of best Yorkshire and other high-grade irons. Ironmasters have learnt by experience what modifications of reheating and re-rolling, combined with variations in the original pig-iron mixture, will produce the best results for each particular section.

The Puddling Process.

The various stages and reactions of the puddling process are described in most metallurgical textbooks, and the reader is referred to the short bibliography at the end of this chapter. The ideal pig iron for puddling purposes has an approximate analysis:

Silicon	1·75
Sulphur	As low as possible.
Phosphorus	0·75
Manganese	0·75

It is a grey forge iron, with an open " rose " of fine crystals in the centre of the fracture. Such pig iron was the " natural " product of blast furnaces working on the clay-band ironstones of Staffordshire, Yorkshire, and Scotland, and explains why it should be in these districts that wrought iron manufacture grew and developed.

Up to a certain stage the puddling process is a small scale replica of open hearth practice. The impurities are removed by a highly basic slag, but when the crystals of pure iron begin to form, the temperature of the furnace is below their fusion point. These crystals are, therefore, in a plastic stage during almost the whole of the first operations, and free to arrange themselves in the most stable internal and relative arrangements. In steel ingot production, on the other hand, the crystals grow within a limited space in the form of long, brittle, " dendritic " crystals. The whole of the subsequent rolling or forging operations have as one of their objects the breakdown of this dendritic structure.

Further Treatment in the Forge.

The first product of the forge is a slab, bloom, or rolled bar. This is cut, piled, and reheated in what is known as a " ball-furnace." Many ironworks have both gas-fired regenerative and the older coal-fired reheating furnaces. Superstitions die hard in the iron trade. Consumers may be prejudiced against one or other of these methods of reheating iron, and both are in consequence retained.

Mill Reheating.

The final product of the forge is again cut, and piled into piles 2 to 6 feet in length and of varying height, charged into a reheating furnace, and raised to a welding temperature. They are then withdrawn and rolled down into the finished section.

Puddling Research.

The manufacture of wrought iron, as very briefly outlined above, is obviously exposed to serious disadvantages under modern conditions of keen competition. It is produced in small quantities; it requires highly skilled labour of a type which is yearly becoming more difficult to secure and retain; and owing to the low output the fuel consumption is relatively high.

The iron trade has been fully alive to these defects since first its position was seriously challenged by the advent of steel. Between 1865 and 1885 research was actively prosecuted mainly with the object of transferring the arduous part of the puddlers' duties to some form of mechanical appliance. The experiments followed in the main three lines of attack:

1. Mechanically actuated rabbles.
2. Movement of the furnace: (*a*) on a vertical axis; (*b*) on a horizontal axis; (*c*) on an inclined axis, or (*d*) a rocking type of furnace.
3. Gas-fired puddling furnaces.

Numerically, the first of these classes was by far the most significant, and it is difficult to realize in the light of later knowledge how much energy was expended on mistaken lines. From the point of view of successful working furnaces revolving on a horizontal axis, of the Danks or Casson type, gave the most promising results.

Success was very near when the overwhelming tide of steel caused most ironmasters to abandon these experiments. Those who have had the faith and the vision to continue, and who now, seeing a rising tide of feeling in favour of the best wrought iron, are providing the material for a second chapter in the history of puddling research.

In 1919 the British Iron Manufacturers' Puddling Research Association was formed under the ægis of the Department of Scientific and Industrial Research. Experiments were initiated following on the lines indicated as most likely to prove successful from the experience of forty years ago.

Progress in the design and assembling of a new plant and the learning of a technique forgotten for forty years was necessarily slow. The abnormally bad trade conditions of the past three years have adversely affected the experiments. But wrought iron has again been made successfully in a mechanical puddling furnace. Trade depressions stifle research, and could but some prospect of industrial peace, some augury of better times to come, be assured, this would provide the stimulus and the means to continue these most promising developments.

Testing of Wrought Iron.

Tensile.

The ultimate strength of wrought iron, with the grain, varies from 20 to 27 tons. The stress-strain curve shows a limit of proportionality at 9 to 13 tons, and a yield point, or commercial " elastic " limit, at 12 to 18 tons. The tensile properties of wrought iron are affected considerably by the size of section, owing to the varying degree of mechanical work to which the iron has been subjected in the process of rolling. The smaller the section, the higher the tensile strength obtained. Also, in general, the better the quality of iron from the point of view of resistance to shock, the lower is its ultimate strength, down to a limit of 21 tons per square inch. The ductility, as measured by elongation and reduction of area, is proportionally greater. Intermediate qualities, and in particular cable iron and iron for smithing purposes, are marked by a slightly higher tensile strength.

Working Tests.

Specifications for wrought iron invariably include a certain number of the following " working " tests, according to the quality of the iron required.

1. Tests of hot working: (*a*) Hot bends—the iron bent flat on itself at 1,000° C.

(*b*) Ramshorns—at 880° C.; a very severe test for red-shortness. (*c*) Quench tests—from 1,100° C.—a guarantee against hardening.

2. Tests of cold working and toughness: (*a*) Simple cold bends, over varying radii depending on the quality. (*b*) Double cold bends—in two directions at right angles; prescribed for staybolt and rivet iron. (*c*) Nicked bend test: a guarantee of fibre. (*d*) " Best Yorkshire " fracture: the sample is nicked all round to localize the path of fracture and broken off short. The sample should show a 100 per cent. finely crystalline appearance—a guarantee of uniformity and even slag distribution. (*e*) Threaded cold bend: a screwed test specimen is bent cold over a radius of 1 to 1½ diameter—a most stringent test for iron of boiler stay quality. (*f*) Cold riveting test, for staybolts. (*g*) A plating test, for malleability.

These qualitative tests are occasionally supplemented by modifications of the Arnold and Sankey or other vibratory tests. In the case of wrought iron chain cables, as is well known, these are " proofed " at some public proving station before being put into use. The number of " working " tests which have been devised, and which are required for any consignment of wrought iron, is considerably greater than in the case of steel. Their value, as indicative of quality, is proportionately higher, and more stress is laid upon them than upon more quantitative tests in the inspection of material.

Chemical.

Chemical tests for wrought iron are seldom specified. This is due to the fact that the analysis of iron is not of such vital importance as in the case of steel, and, further, the results are apt to be misleading. The amount of mechanical work which has been put upon the iron during the course of its manufacture and the character of that work, whether rolling or hammering, together with the subsequent treatment of the iron, exert a far greater influence upon its mechanical properties than does the chemical analysis. The typical analyses of different grades of iron are given below:

	Best Yorkshire.	*Grade A.*	*Grade B.*
Silicon	0·10	0·13	0·15
Sulphur	0·015	0·02	0·025
Phosphorus	0·12	0·18	0·22
Manganese	0·03	0·05	0·08
Carbon	0·02	0·03	0·04

In the interpretation of the chemical analysis of wrought iron, it must be remembered that this material consists essentially of nearly pure iron and included slag. This slag is puddlers' tap cinder, containing up to 3 per cent. of phosphorus and 16 per cent. of silica, and amounts to about 2·5 per cent. of the total bulk of the iron. A total phosphorus content, which would be fatal in the case of steel, may thus accompany a relatively pure and tough wrought iron. In fact, up to 0·25 per cent. of phosphorus, in so far as it implies the presence of slag to act as a flux, is actually beneficial for chain iron, and wherever the iron is required for welding. The maximum manganese content of 0·10 per cent. is occasionally specified as a protection against the admixture of steel.

Microscopic.

The microscopic study of wrought iron, at first sight a comparatively simple proposition, appears on further investigation to be much more complex, and offers considerable possibilities to future research. It is true there are only two components—ferrite and slag threads. But the ferrite varies in grain size and internal stability according to the previous mechanical and thermal treatment. The slag threads exist in two or three modifications, and divide the iron into a series of layers of ferrite, so that the whole is comparable to the structure of a wire rope, with its consequent powers of resistance to sudden stresses. The essential difference between wrought iron and mild steel lies in the mode of formation of the groups of crystals comprising the structure. In the latter case the crystallites grow promiscuously from a number of nuclei; in the former they are in a plastic stage from the moment of their formation in the bath of the puddling furnace, and free to take up the most stable orientation among themselves.

In the account of the " working " tests of iron reference has been made above to the 100 per cent. crystalline best Yorkshire fracture. The precise significance of this test is sometimes not a little puzzling to consumers of high-grade wrought iron. " Why," it is asked, " should fibre be insisted on in lower grades of iron, and 100 per cent. crystal in the best iron which is made ?" The distinction is a very important one, and involves no little knowledge of the structure and manufacture of iron.

To obtain the 100 per cent. best Yorkshire fracture the sample is nicked all round. This localizes the path of fracture. If the test piece were to be nicked on one side only and then fractured, the crystal columns separated by slag threads would move over one another and the result would be a fibrous break. But if there is no time to allow this relative movement, and also if the slag is reduced to the minimum consistent with shock-resisting qualities, the fracture travels across individual crystals and presents a number of crystal facets to visual inspection. Now it will be found that the number of these per square inch is very considerably in excess of the number which can be observed in the coarsely crystalline appearance of poor iron. The result is that with best Yorkshire iron 100 per cent. crystal and 100 per cent. fibre can be obtained within a few inches of each other, depending on the manner of nicking. Also the 100 per cent. crystal has given the user a guarantee that the iron is uniform, is free from dirt or cinder, and that the slag threads within it are present in exactly the correct proportion.

During the post-war years a very considerable tonnage of so-called wrought iron has been imported into this country from the Continent. The bulk of this is not genuine puddled iron at all, but a heterogeneous mixture of iron and steel scrap. In the process of its manufacture a composite pile of iron and steel bars or billets is heated and rolled down. The satisfactory welding of such a mixture is regulated by the welding temperature of the iron. This is much above the working temperature of steel, and the result is invariably an overheated, brittle structure which is bound to result in failure sooner or later. Again, if this material

is subject to corrosive influences, electrolytic action is set up and both the iron and steel rust away more rapidly than would either individually.

It is in their own interests that consumers of wrought iron are urged to insist upon genuine 100 per cent. wrought iron. Steel scrap can easily be detected by both chemical and microscopic means, and this influx of Continental admixture of iron and steel serves only to discredit the product of one of the oldest British industries.

Brands, and how to Order Wrought Iron.

In 1910 the British Engineering Standards Association issued the British standard specification No. 51 dealing with wrought iron for railway rolling stock and defining the tests for best Yorkshire and Grades A, B, and C. The Committee " did not consider it desirable to perpetuate the terms ' best,' ' best best,' and ' treble best ' as applied to Staffordshire iron." Nevertheless, these terms have continued and are likely to do so for a great many years to come. In conjunction with a maker of experience and repute they imply a definitely high standard of quality. Further, they supply the needs of consumers who require a standard of quality intermediate between Grades A and B, or Grade A and best Yorkshire.

It cannot be over-emphasized that the purchase of wrought iron is not based on quantitative tests to the same extent as steel. The very properties for which wrought iron is so often specified—welding, resistance to corrosion, etc.—cannot be expressed numerically. This is the province of the " marked bar " qualities, and certain brands of iron have long held a reputation for smithing and welding qualities, for reliability and ductility, and are never ordered on the basis of the tensile test.

To those engineers, works managers, store-keepers and others who may have occasion to specify or order wrought iron the following points may be of service:

1. Order from a firm of experience. Iron-making is not learnt in a day.
2. Be sure of obtaining 100 per cent. wrought iron. A mixture of iron and steel is worse than either individually.
3. Indicate, as far as possible, the subsequent treatment which the iron will receive.

Considerable disappointment has been occasionally experienced by consumers because iron did not come up to their expectations. On investigation it has been found that they were attempting to work the iron in a manner which, if the maker had known beforehand, the process of manufacture could have been altered or modified to suit the particular requirements. It must be remembered that the manufacture of wrought iron is no stereotyped series of operations, but the number of variations is almost infinite.

The Properties of Wrought Iron.

Resistance to Corrosion.

In venturing to deal with the subject of corrosion one feels like a traveller on a well-worn highway, overwhelmed with conflicting signs and warnings from the experience of others. Laboratory tests on corrosion are notoriously contradictory and difficult of interpretation. Indeed, from the nature of the case it could hardly be otherwise, since the resistance to corrosion which matters commercially cannot, unfortunately, be measured by experiments lasting a few days or months, conducted under fairly constant arbitrary conditions. Conclusions must be drawn from a consensus of opinion representing the fruit of many years' experience and exposure to all possible conditions of climate and weather. From all parts of the world—from the Australian farmer who requires durable fencing, the Argentine merchant who needs corrugated sheets for his warehouses, the South African waterworks engineers, who had to replace a large steel water main in 1912 with one of wrought iron, and from the maintenance engineers on our home railways—there are indications that wrought iron gives unquestionably a longer service than mild steel.

Fish-wagons and wagons containing washed coal on our English railways are fitted with wrought iron underframes, because it was found that the constant drip of water corroded away steel underframes in one-eighth the lifetime of wrought iron. These alternate " wet " and " dry " conditions, together with the inaccessibility of wagon underframes for purposes of scraping and painting, render wrought iron peculiarly suited to this class of traffic.

Blast furnace stoves are in existence with wrought iron casings which have withstood twenty or thirty years of exposure, and have seen three or four stoves of mild steel come and go.

Over many a Black Country forge there stands to-day a wrought iron roof as good as when it was erected forty years ago. Mild steel roofs in the same district need replacing after five years.

Colliery tubs and drawgear working underground in damp conditions must be of wrought iron if the cost of renewals is not going to make too big a hole in the profits.

One of the largest gas companies in the country found that a whole outfit of mild steel pipes had to be taken up and replaced after three or four years in the ground. The only portion of the outfit that could be used over again were the small wrought iron fittings at various points in the system.

The case of the first gas holder to be erected in England is historic. This was at Soho, Birmingham, and was erected by Murdoch in 1792. After 120 years' service in an atmosphere heavily laden with chemical fumes this structure was dismantled in 1912. It was built of common wrought iron plates.

What is the reason for this wonderful longevity of wrought iron? It is not purity. It is those protecting slag films that surround the crystal columns, protecting the iron from corrosive influences, like the cement in ferro-concrete work.

Resistance to Shock.

What is the precise meaning of " shock " or " impact " in engineering parlance ? It is a sudden stress of only momentary duration which exceeds the elastic limit of the material. It results in a condition of overstrain, and some measure, however small, of permanent deformation. The structure is hardened and embrittled. Further shocks increase this undesirable state of affairs, and eventually " the last straw which breaks the camel's back " results in catastrophe.

How can this " overstrain " be removed and the material brought back to its normal condition ? By rest, by annealing in a furnace to a certain critical temperature, and sometimes by exposure to moderate temperature, as by immersion in boiling water. But it is not practicable to remove a structural member or a machine element after each and every shock to which it is subjected and submit it to this " healing " operation. The material has to be left to look after itself.

The materials of engineering differ considerably in their capacities to accommodate sudden stresses. Lead, for instance, is so soft that it will " flow " under any excessive overload. Tool steel, on the other hand, will snap off " like a carrot." Again, most metals are so constituted that they have a potential ability to recover themselves from overstrain. But the *rate of recovery*, which is the determining factor, is not always sufficiently high.

Researches, which have recently been conducted by a Government Department from an entirely independent and unbiassed point of view, have demonstrated that with wrought iron this rate of recovery is so high that it is taking place appreciably all the time a load is being applied. This is not the case with rolled, cast, or alloy steels. The natural corollary is that wrought iron is the material *par excellence* for withstanding impact.

This only bears out what has been the almost universal experience of colliery and railway engineers. Wherever human life is in the question, wherever " Safety First " is the ruling principle, colliery engineers specify best Yorkshire or other high-grade wrought iron. It costs more initially, but the risk of using any other material is too expensive to be run. No one who has ever watched railway shunting operations would deny that the ubiquitous wrought iron wagon coupling and wrought iron drawgear are subjected to tremendous " shock " effects. Indeed, it has been remarked that no item of engineering structure is so habitually loaded to a capacity greater than that for which it was designed as are chain links and couplings.

Welding.

To assert that all welding should be avoided is a counsel of perfection. Unfortunately, welds are one of the unavoidable necessities of engineering practice. It is important, therefore, to ensure the success, as far as possible, of an operation in which the personal equation looms so largely. Wrought iron is admittedly the premier material for welding purposes. The claim is based, not only on scientific facts, but on the everyday experience of the repair shops of railways, shipyards, collieries, iron and steel works, and of the smithies and forges of Europe.

The Properties of Wrought Iron.

Resistance to Corrosion.

In venturing to deal with the subject of corrosion one feels like a traveller on a well-worn highway, overwhelmed with conflicting signs and warnings from the experience of others. Laboratory tests on corrosion are notoriously contradictory and difficult of interpretation. Indeed, from the nature of the case it could hardly be otherwise, since the resistance to corrosion which matters commercially cannot, unfortunately, be measured by experiments lasting a few days or months, conducted under fairly constant arbitrary conditions. Conclusions must be drawn from a consensus of opinion representing the fruit of many years' experience and exposure to all possible conditions of climate and weather. From all parts of the world—from the Australian farmer who requires durable fencing, the Argentine merchant who needs corrugated sheets for his warehouses, the South African waterworks engineers, who had to replace a large steel water main in 1912 with one of wrought iron, and from the maintenance engineers on our home railways—there are indications that wrought iron gives unquestionably a longer service than mild steel.

Fish-wagons and wagons containing washed coal on our English railways are fitted with wrought iron underframes, because it was found that the constant drip of water corroded away steel underframes in one-eighth the lifetime of wrought iron. These alternate " wet " and " dry " conditions, together with the inaccessibility of wagon underframes for purposes of scraping and painting, render wrought iron peculiarly suited to this class of traffic.

Blast furnace stoves are in existence with wrought iron casings which have withstood twenty or thirty years of exposure, and have seen three or four stoves of mild steel come and go.

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Some of the Special Uses of Wrought Iron.

Railway Engineering.

Wagon underframes, coach and wagon couplings, drawbars and Gedge's hooks, wheel spokes and wheel centres, locomotive staybolts and boiler stays, buffer plungers, wagon brake guards, forgings, crane chains and hooks, spring buckles, axle guards, brake pull rods, corner plates.

Shipbuilding.

Chains and stud link cables, end and joining shackles, swivels and towing slips, mooring chains and mooring rings, mooring buoys, grapnels, anchors, marine boiler stays and boiler tubes, rivets, marine shafting.

Colliery Engineering.

Cage suspension chains, safety detaching hooks, haulage chains, drawgear and couplings, rope grips, horse shoes.

Gas and Water Engineering.

Welded tubes, pipes, and fittings for distribution systems, particularly for damp and underground conditions, gasometer guide rails and chains.

In 1920 the output of wrought iron tube strip accounted for 14·1 per cent. of the total output of finished iron.

Textile Machinery.

Bright shafting, roller iron, case-hardened gears and screws, bobbin spindles.

Wrought iron is extensively used for shafting in textile machinery on account of its superior flexibility and capacity to adjust itself to slight vibrational stresses, which would otherwise interfere with the smooth running of the machinery.

Roller iron is an exceptionally pure iron, very free from slag, and will run in brass bearings without lubrication. Steel rollers wear gritty.

Bobbin spindles are cold riveted.

Miscellaneous.

Quartz-crushing machinery; stamper stems and cam shafts (subjected to excessive vibration and repeated impact effects. Only wrought iron has been found by experience to give satisfactory results); disintegrator and agricultural machinery (a wrought iron backing is provided for a hardened steel face, combining flexibility with wearing qualities); " combined iron and steel " for saw bands and cutting tools; brewers' and coopers' hoops; foundry moulding boxes; pulleys and shafting and numerous engine details; wheels for electric tramway cars (see B.S.S. No. 149); horse and mule shoes; special sections for milk-can rims, window sashes, boat guards, etc.; ornamental ironwork for gates, screens, etc.

Some Potential Uses for Wrought Iron.

Structural Engineering.

It is now almost forty years since the wrought iron bridge began to disappear and its place was taken by steel. But the most rapid period of railway development took place before 1880. There are, in consequence, in this country to-day many scores of bridges built exclusively of wrought iron. Any one of them may be said to have already had an existence of one and a half to twice the life of any steel bridge. They are annually bearing heavier and heavier loads; in many cases twice the load for which they were designed.

From the point of upkeep, and protection from the ravages of corrosion, it is only necessary to contrast the history of the Forth Bridge subsequent to its opening in 1890 with that of the Menai Tubular Bridge (1850), the High Level Bridge at Newcastle-on-Tyne, the Clifton Suspension Bridge, or a score of other wrought-iron structures. The words of an eminent railway engineer in 1906 leave no room for doubt: "No iron bridge, however old, rusts as quickly as do the new steel bridges" (see *Proc. Inst. C. E.*, vol. clxii., p. 213).

Again, from the point of view of resistance to impact wrought iron has much to recommend it. The late Sir Benjamin Baker on many occasions expressed surprise at the capabilities under most stringent conditions of the best wrought iron, and Kenworthy (see Bibliography) gives interesting figures of economies possible by the partial use of wrought iron in cross girders and stringers more particularly subject to an impact effect.

The objection is sometimes raised that wrought iron cannot be made in large sections. It is true that the limits of size are much lower than for steel, but the perusal of makers' section lists would elicit surprise from many engineers.

Among the suggested uses of wrought iron in structural engineering are the following: piers, jetties, caissons, and all work on the sea-line which is subjected to alternate wet and dry conditions; piles; bridgework—particularly for members subjected to impact, and for use in damp tropical climates.

The use of wrought iron for ferro-concrete work is advocated by certain Continental engineers.

The Markets for Wrought Iron.

The total British production of finished iron in 1913 was 1,121,232 tons. The exports of bar iron for that year were 141,452 tons—roughly 12·6 per cent. of the total output. To this export figure must be added 164,556 tons of "wrought" tubes, pipes, and fittings, bringing the total percentage of wrought iron, which ultimately found its way abroad, up to 27·3 per cent. of the total output. Statistics of home consumption are not, of course, available. The home consumption of wrought iron would naturally be spread over those fields of engineering which are indicated above, and in the relative order of tonnage in which the uses of wrought iron have been tabulated—railways, shipbuilding, collieries, textile and miscellaneous.

The bulk of the British wrought iron export trade, in common with the steel trade, is Colonial. The following table shows the percentage distribution according to the most recent available statistics. It will be seen that the Eastern market—India, Australia, New Zealand—accounts for approximately half of the total exports. The increase in exports to India in 1921 and 1922 has been due to extensive railway development in that country. Australian demand shows a slight falling off as compared with the pre-war period. The Canadian consumption is disappointing, due to a certain amount of competition from U.S.A.

PROPORTIONS OF THE EXPORTS OF BAR IRON FROM THE UNITED KINGDOM TO VARIOUS COUNTRIES, 1913, 1921, AND 1922 (PER CENT.).

	1913.	1921.	1922.
Australia	28·6	10·7	21·8
New Zealand	11·6	6·1	17·2
India	9·4	25·7	24·6
South Africa	10·0	7·6	7·1
Canada	6·6	2·0	3·0
Other British Possessions	9·4	17·1	10·5
South America	12·5	10·4	4·6
Other foreign countries	11·9	20·4	11·2
Total	100·0	100·0	100·0

BIBLIOGRAPHY

THE most complete account of the manufacture of wrought iron is contained in Turner's *Metallurgy of Iron*, published by Griffin.

No complete account of the history of the wrought iron trade is extant. Reference may be made to Scrivenor's *History of the Iron Trade* (1854), Griffiths's *Survey of the Iron Trade in* 1875, and to the statistical reports of the National Federation of Iron and Steel Manufacturers and its predecessors.

Puddling research is admirably summarized by Desch in the *Proc. Staffs. I. and S. Inst.* and *West of Scotland I. and S. Inst.*, 1918-19, where full references will be found.

Theoretical considerations affecting the puddling process are treated by J. E. Fletcher in numerous illuminating communications to the South Staffs. Inst. (see, *e.g.*, March, 1914; April, 1915; Nov., 1919).

Roe, *Journ. I. and S. Inst.*, 1906, vol. iii., p. 264, discusses puddling reactions in connection with his mechanical process.

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CHAPTER VI

*FORGINGS**

The origin of the art of forging is lost in the mists of antiquity, but there can be little doubt that it formed one of the earliest developments of human effort. The necessity of possessing efficient lethal weapons would cause primitive peoples to look very carefully into any improvements which may have appeared possible. The fact that stone or flint axes were brittle and unreliable would form a strong incentive for the adoption of more dependable material. A casting of tin or copper would be the first step, owing to the low melting-point of these metals rendering the accidental discovery of molten metal possible. Probably meteoric iron was the first form of ferrous metal to be used, and this would be forged by the primitive blacksmith into swords and axe-heads. Progress, doubtless, was slow, but we know that by the Middle Ages man had acquired a great mastery over malleable iron, and the beautiful specimens extant show that craftsmanship had attained a level in hand forging that has even now never been surpassed.

With the introduction of larger sailing ships and primitive machinery on land, such as wind and water-mills for grinding corn, etc., forgings of larger mass would find an increasing demand, and the progress in this country from about the sixteenth century has been continuous. The first application of power for forging purposes was probably developed from the water wheel, and there are now, still actually at work near Sheffield, one or two of the old water "tilt hammers." The principle of this design was to lift a heavy hammer head attached to a strong oak beam pivoted at one end, by means of pins fixed at intervals round the circumference of a wheel which was rotated by water power As each pin came into contact with the pivoted beam, the latter was lifted and allowed to fall by gravity, striking the object to be forged, which was held in place on an anvil. It will be seen that by this process it was not possible to vary the power of the blow, as the beam was always lifted to the same height, and the weight of the hammer head, of course, remained constant. This method remained in vogue until the introduction of steam power, and it is interesting to record the wonderful structures which were successfully produced by this method and by hand forging. For instance, the Menai Suspension Bridge connecting Carnarvonshire and Anglesey, designed by Telford, was built entirely of forged iron links before the introduction of steam power, and so efficient was the work that the bridge has survived to this day, and its replacement by a stronger structure is only now under consideration.

The next great step in the development of forging was due to the genius of Nasmyth, who invented the steam hammer in 1842. The advantages of this new device were such that it was very widely adopted in a very short space of time. With this tool the most delicate control could be obtained. From a

* By A. J. Grant, of Messrs. John Brown, Ltd., Sheffield.

giant hammer, with a head weighing many tons, with the full force of steam behind it, and capable of giving such a blow that the heaviest masses known at that period could be readily and efficiently forged, so light a stroke might also be made that the glass of a watch lying on the anvil could be broken without in any way damaging, or even stopping, the watch. Steam hammers continued to be developed in various ways until about 1880, when the rapid increase in size and horse-power of war vessels and ships of the mercantile marine caused a demand for still larger forgings, and it became evident that this demand could not satisfactorily be met by steam hammers. It will readily be understood that ponderous steam hammers necessitated enormous anvil blocks and extremely solid foundations, and even then difficulty was constantly experienced after the hammers had been at work for some time, owing to the jar and vibration disintegrating even the most elaborate foundations.

It is a very interesting fact that at the time of the development of the steam hammer a fundamental revolution was also taking place in the metallurgical world. Hitherto, forgings had been made of wrought iron, and the larger forgings had been produced by "piling" smaller pieces—*i.e.*, forging together small components to make a large mass. The tensile strength of such material was limited to just over 20 tons per square inch, but a large forging made in this way had its strength materially reduced by the cinder unavoidably present through the method of manufacture. In the early sixties the Bessemer process for the production of mild steel rapidly came into use, and large masses of homogeneous mild steel became available, better suited for the purpose required than the wrought iron hitherto employed. A little later the Siemens process of steel manufacture came into vogue, which, as a result of the development in size of such Siemens furnaces, rendered it possible to cast masses of mild steel out of all proportion to the weights which engineers had previously had in mind.

About this time the hydraulic forging press made its appearance, and it is this machine which, with many improvements in detail, has held the field up to the present time. In addition to the advantage of quiet working and the greatly enhanced power available, the forging press possesses many advantages over the hammer from a technical forging point of view. The hammer head, descending with high velocity, tended to put all the "work" (or alteration of form) on the exterior portions of the forging which were immediately subjected to the blow, and to leave the centre of the forging practically "unworked," with its original coarse ingot structure undisturbed. The press, on the other hand, exerts a slow uniform pressure on the mass of steel, and the effect of the work penetrates to the centre of the core, resulting in a forging having a more uniform structure throughout, and the finished product in consequence showing far better mechanical properties when tested. The difference in the method of deformation between the hammer and press processes is now explained satisfactorily by our new knowledge of the properties of steel at high temperatures. Hot steel under a static load behaves as a viscous fluid, and therefore the deformation tends to become uniform throughout the mass, whereas under dynamically applied stress—*i.e.*, a hammer blow—the steel responds as a true solid, only the exterior tending to be completely deformed in the time available.

Forging presses have been developed to keep pace with the demand for large forgings, and presses are now in operation capable of exerting a pressure of 10,000 tons or more, and which can deal easily with ingots up to 150 tons in weight.

It may be of interest to glance at the manufacture of, say, a large propeller shaft in a modern steel works. Let us suppose that a shaft has to be produced of the size required for H.M.S. *Hood* (one of the largest ever made). With the order for the shaft will be specified that a test piece cut from the finished forging must give a certain tensile test, coupled with a definite amount of elongation before fracture, and that another piece cut from the shaft must be capable of being bent cold through 180° without sign of fracture. The steelmaker decides the necessary analysis to which the ingot shall be made to give the required tensile strength. The forgeman settles the weight required, due allowance being made for parting off the upper portion of the ingot. The ingot is then cast, and when it has solidified it is charged into a reheating furnace, and gradually and uniformly heated until the required forging temperature is attained. It is then lifted out of the furnace by an overhead electric crane, probably capable of lifting 200 tons. It is put under the press, and gradually forged down to the requisite shape and size, several heatings probably being required for this purpose. The shaft to which we referred above weighed 80 tons, was nearly 70 feet long, and 30 inches in diameter when it was finished as a forging. When the work at the press is completed, the forging is subsequently carefully annealed, tested, and sent to the machine shop, where it is turned and bored, and eventually sent to the shipyard. It is there finished, machined, and finally placed in its working position, where it commences an arduous existence, with violent and searching fluctuations of stress, which would inevitably reveal any defects which were latent in the forging, and which, in case of failure, might leave a mighty vessel helpless on the high seas. Small wonder that large forgings are the subject of anxious care throughout the throes of their birth.

The last twenty-five years of the nineteenth century have been also remarkable for another development, this time relating to composition instead of process. Various investigators made experiments, which consisted of alloying other metals with steel, and remarkable results have ensued. The ordinary mild steel forging is a homogeneous solid mass of steel which owes its increased strength over wrought iron to the presence of a small proportion of carbon and manganese. It was, however, found that if nickel and chromium were alloyed in the steel, the largest masses could be oil-hardened and subsequently tempered. The importance of this development cannot be exaggerated, rendering possible the production of the heaviest forging which might be hardened and tempered, and possess properties similar to those which previously could only be obtained in various small articles. A gun forging weighing many tons can now be as effectively hardened and tempered as a small sword or dagger was hundreds of years ago.

It is in the manufacture of war material that the greatest experience has been gained in forgings of high quality, for the manufacture of which alloy steel has been employed. Happily this experience is available for peaceful purposes, and it is along these lines that the modern forgemaster is developing. Steels con-

taining alloys such as nickel, chromium, molybdenum, vanadium, etc., all present their special problems, but if the experience already gained is carefully applied, most remarkable results can be, and are being, obtained by British forgemasters. New methods of testing are continually being evolved, each new test being designed to discover the presence or absence of some particular characteristic, such as brittleness, resistance to fatigue, etc. It is in quality rather than quantity that this country can best hope to maintain its supremacy in forgings. Great Britain is not well placed for the manufacture of cheap low-grade steel. Her natural resources of ore are poor, and her transport charges are high. Her fuel certainly is abundant, and the best in the world for metallurgical purposes; but the present high cost of coal is a very serious factor, and affects vitally the prospects of prosperity in the forging trade. There is no doubt also that the general standard of living of the men engaged in the steel trade in this country is on a higher level than those of her Continental competitors. It is for these reasons that it is essential that British-made forgings should be synonymous with good quality, and this fact is deeply implanted in the minds of all the leading manufacturers at the present time. As production of higher-grade steels develops, so will marine, railway, road, and air transport continue to increase with greater reliability and more efficiency.

It has been truly said that the material prosperity of a country is very largely in the hands of its engineers. An engineer, however skilful in the design of new devices, and however bold in his application of them, cannot achieve success if he is unable to obtain reliable material, nor can he advance greatly over his predecessors unless that material can be worked into shapes hitherto unattempted, and exhibit properties hitherto unattainable. It is in these directions that the metallurgist and the forgemaster can assist in the progress of the human race, and great as has been the progress in the past, there is no reason to think that finality has been reached, nor that the developments which may be expected in the present century will not dwarf all that has gone before.

It may be of interest to prospective purchasers of forgings to give a few particulars to enable enquiries to be sent in a form which can be readily dealt with by makers in this country.

Forgings for marine purposes are, as a rule, ordered in accordance with the tests and inspection of Lloyd's Register of Shipping, Board of Trade, Bureau Veritas, etc. All these organizations lay down definitely the sizes of the test pieces and the physical properties which are necessary to satisfy their requirements. Full particulars are to be found in the various publications issued by the bodies in question, but, roughly speaking, it may be said that marine shafting is usually made from carbon steel with a tensile strength of about 28 to 32 tons. Forgings required for turbines are frequently of a somewhat higher tensile strength, ranging from the figures given above to about 34 to 38 tons. In the case of geared turbines very special attention has been paid to the material required for the toothed pinions and gear-wheel rims, and special specifications have been prepared and adopted in this country to govern the manufacture of these very important items. Full particulars of these specifications can be obtained from any recognized forgemaster.

Forgings required for land purposes are very well covered by the specifications issued by the British Engineering Standards Association, which give full particulars for all classes of steel. In the case of heavy electrical machinery these specifications have been amplified and elaborated by the British Electrical and Allied Manufacturers' Association, known shortly as B.E.A.M.A., and have been agreed upon between the makers of electrical machinery and the forgemasters after prolonged discussion, and may be said to represent the ripest experience available for work of this nature.

Miscellaneous forgings are very frequently enquired for without having any definite tests specified, and it is advisable for purchasers in cases such as this to indicate to the forgemaster the purpose for which the forging is required, and if the purchaser has any doubt as to the most suitable material to be used, full advice will readily be given. All enquiries should be accompanied, wherever possible, by sketches showing the finished article, and the forgemaster will make the necessary allowance for supplying forgings either in the black state or preferably rough machined to sizes slightly larger than the finished dimensions.

Abrupt changes of section should not be incorporated in designs if they can possibly be avoided, as failures of forgings frequently occur from want of knowledge on the part of the designer as to how the forgings are actually made. These remarks apply particularly to high tensile alloy steel forgings, which have to be heat treated. These abrupt changes and sharp edges are very liable to give rise to incipient cracks, which may develop in use and cause failure, which could easily have been avoided if the principles on which a forging is made had been grasped in the first instance.

CHAPTER VII

*HEAVY STEEL CASTINGS**

THE developments in the processes of steel manufacture, which formed an important feature of the last half of the nineteenth century, have rendered it possible—for instance, in the Siemens Open Hearth process—to make single casts of steel of 50 to 100 tons and more in weight. This means that liquid steel is now available in large bulk, which enables castings of very considerable dimensions to be manufactured. In connection with the construction of ships, turbines, and power plants of various kinds, the facility for casting to shape large, heavy, and intricately designed parts is necessary, and it is, in fact, this ability of the steel firms to make such castings that has rendered possible some of the later developments in modern engineering. Castings are now manufactured up to 100 tons in weight, and as regards dimensions the stern frame for a ship may be instanced, which is not even one of the heaviest castings, yet occupies a very large space during manufacture in the foundry, and frequently presents great difficulties in transit afterwards. It will be understood that the modern engineering works can now be served, as regards steel castings, in a vastly different manner from the way in which they were dependent upon steel

* Contributed by Messrs. Thomas Firth and Sons, Ltd., Sheffield.

manufactured by the crucible process, although, indeed, having in mind the facilities then available, some very fine castings, though of smaller dimensions, were made in the early days of last century.

When a large weight of liquid steel is poured into a mould, that liquid steel has to solidify in position, and a good deal of contraction (external and internal) takes place. It is upon the skill of the people engaged in the foundry, in so arranging the moulding and casting operations that the casting itself is free from serious internal defects due to this cause, that the success in service of these important large castings depends. Very great strides have been made with regard to the properties of these large castings. For instance, up to comparatively a few years ago it was considered that a steel casting as cast could be put into service, but careful scrutiny of the characteristics of the steel as cast, in the light of the onerous work required in modern conditions, has clearly shown that it will not do to put a steel casting into service in the condition in which it is cast. The cooling down from the liquid state results in much stress being left in the casting; indeed, sometimes the casting is so affected by the stress left as a result of manufacture that it has been known to break in service. A study during recent years of the true nature and constitution of cast steel has enabled the foundry to devise methods of reheating and annealing the steel, whereby properties of strength and toughness can be introduced into these large castings approximating very nearly to those obtained in forgings, which same processes also result in the dangerous internal stresses being removed.

It is of interest to observe that in the large works where the bigger castings are made steel of the same high quality as that used for the production of large forgings is used for pouring into the moulds, so it may be taken that in the production of castings for marine engineering, turbine engineering, and railway and other branches of engineering, the quality, strength, and toughness are all that can be desired.

It is, of course, obvious that the management and running of a large steel foundry demand the services of men who are highly trained technically in the various branches of metallurgy and engineering, and it will indeed be found that much of the best technical talent of the country is now associated with this branch of the steel industry. Indeed, this needs must be so, since otherwise it would be impossible to manufacture successfully some of the more important castings required. Their design and configuration, as has already been pointed out, is often most complicated, and the more varied the form of the casting, the more difficult does it become to ensure its freedom from defects. Fortunately, however, there has been an increasingly satisfactory contact between the technical staffs of the steel foundries and the technical staffs of engineering organizations who have to use the castings, and it is now not an uncommon thing for an engineering works requiring a large casting to ask for the foundry manager and pattern-maker to join in the discussion as to details of the design which is being produced. There is, indeed, still much more that can be done in this direction, since only by complete collaboration between the designer and the producer can the most satisfactory results be obtained. The designer cannot know too much concerning the art of steel founding if he is to utilize the foundry to the best advantage.

Adjoining thin and thick sections, thick sections and heavy bosses in inaccessible places, heavy bosses attached to thin general sections of metal, sharp angles insufficiently radiused, and many other similar bad features of design from the founder's point of view, should be invariably before the designer's mind, and, indeed, it is a fortunate fact that the designer of to-day takes an entirely different view of these things from the designer of years ago, who then seemed to credit the steel foundry with the ability to make satisfactorily any casting which the designer's fertile imagination could place on paper.

When a casting has been designed, the enquiry to the foundry should be accompanied with full information. For instance, the foundry should be told which are to be the machined portions, and what are the machining allowances, and should also be told which are considered the most important surfaces. Care should also be taken to specify such mechanical properties as will make the casting easily capable of doing the work for which it is desired. In this connection one might refer to the excellent specifications which are now being issued by the British Engineering Standards Association. In the production of these specifications advantage has been taken of the general knowledge of the leading people in the steel foundry industry, and the consumer can have every confidence that the casting will be reliable in service if it reasonably complies with the figures so laid down.

Turning to the actual manufacturing operations, it is probably not always appreciated that molten steel, hot enough to cast into the form of castings of various sizes and shapes, has an actual temperature in degrees centigrade somewhere between 1,500 and 1,600. Such a temperature is so high that it can be safely stated that if a temperature were required much higher there are no known commercial refractory materials of which the furnace could be built. This fact immediately produces a set of difficulties for the men who have to make the casting. They must find a material of which they can make a mould of the shape required, which will withstand the weight of molten steel without fusing and becoming fixed on to the surface of the steel. This is a direction in which much experiment has been made, and with considerable success, it being found that there are highly refractory materials, such as the better qualities of sand, ganister, and fire clays that, with a suitable admixture of carbonaceous material, produce highly satisfactory material for moulding purposes, which, rammed and moulded into the requisite form, subsequently withstands the steel casting conditions successfully. When the steel has been poured into the mould so produced, it is left to solidify and cool down to a reasonable temperature. The casting is then withdrawn from the mould, dressed, and suitably annealed and heat-treated to confer the required properties upon it. It is then taken to the fettling shop, where all unnecessary material is removed, and is then ready for handing over to the engineering shop or works for which it has been manufactured.

In discussing heavy castings, we have already pointed out that the essential steel-making process used for these is the Siemens open-hearth process. For small castings, modifications of the Bessemer process are still successfully employed, but the latest development of all in steel-making processes—viz., the

electric melting process—has now been found to produce such excellent steel that the use of this for the smaller class of castings is likely to be considerably increased. The greater purity of electric steel has much to commend it.

The particular properties most desirable in a steel casting are naturally determined by the particular service which it has to render. For most large castings which are of a structural nature, the first essential is great toughness combined with reasonable strength. These properties are obtained by making the casting of mild carbon steel containing from 0·20 to 0·25 per cent. of carbon. One particular advantage of this 0·20 to 0·25 per cent. carbon material is that it tends to limit some of the difficulties of the founder; this is particularly so with regard to the prevention of "pulling"—*i.e.*, cracking during cooling down. The production of such mild steel castings has indeed attained a very high standard, and when such castings are properly annealed, the properties are little inferior to forgings. Of course, the forging will always have the advantage of having been made from an ingot—*i.e.*, a casting of simple form in the making of which all other considerations, except producing a mass of steel free from any disability, have been put on one side—whereas in producing a turbine casing, or wheel centre, the shape is the main consideration, and the art of the founder the means of procuring reliability. This emphasizes the point already mentioned of the designer's and founder's intimate collaboration when considering new designs.

The mild carbon steel as described has, under tensile test, a breaking strength of 30 to 35 tons per square inch, together with an elongation per cent. on 2 inches (British Engineering Standards C. test piece) approximating to 30 per cent. A bend test piece of such material will, in the cold, bend 180°—*i.e.*, bend back upon itself without breaking.

In the foregoing, mention has only been made as regards testing of the tensile and bending tests. The modern works are now employing other static and dynamic tests which have been devised to ensure reliability; much of this work is done in the laboratory, but apart from mechanical testing as generally understood, specimen castings are frequently put through destruction tests in the works. Also, where castings are submitted in service to steam or hydraulic pressure, practical tests have been devised whereby the castings are submitted to greater pressures before they are despatched than they will have to withstand in service. Where the casting has to resist higher stresses or greater wear and abrasion, it is desirable that steel containing a higher percentage of carbon shall be used, the resistance to wear increasing as the carbon content is raised. In cases where still greater strength is required, or exceptional wear and abrasion have to be encountered, one of the special steels must be utilized—*e.g.*, nickel or nickel-chromium steel—in which case the casting is hardened and tempered, or manganese steel containing 12 to 14 per cent. of manganese. Castings made of the latter steel resist abrasion very well after being water-toughened by heating to 1,000° C. and plunging in water.

If it is required that the casting shall be rustless, or have high strength at elevated temperatures, then steel is used of the kind of which stainless articles are made—*i.e.*, containing a high percentage of chromium. Castings are now

being successfully made in such steel, and are proving admirable for superheated steam valves, sluice castings, and other purposes, many of which will occur to the mind of the reader. Such castings are very tough, and incidentally have a breaking strength of 45 to 50 tons per square inch.

With this short account, it is hoped that it has been made clear that the art of making castings in steel has kept pace with the great advances of steel metallurgy. As regards the general position, British steel founders will undoubtedly in more normal times hold their own against foreign competition. In a casting, *the highest possible degree of reliability* is essential, and the technical staffs, manufacturing castings in our modern British steel foundries, have the advantage of employing a body of workmen whose skill is unequalled the world over.

CHAPTER VIII

THE SHEFFIELD INDUSTRIES (PROCESSES AND PRODUCTS)

IN the Sheffield district, known as Hallamshire, iron has been worked from the earliest times recorded in the annals of industry. The ancient Britons made iron implements and tools here. The Roman invaders soon learned to appreciate the quality of both the weapons of war and tools of peace produced in this locality. Tax-paying cutlers and arrowsmiths were specially mentioned in the great English Poll Tax Assessment of 1379. The Cutlers' Company, or Commonwealth of Cutlers, was named in Acts of Parliament in 1565 and 1624. In armour, guns, projectiles, swords, knives, tools, saws, etc., Sheffield manufactures have stood on the top rung of the ladder of quality for centuries.

Seventy years back steel was so costly that it could only be used in what are called the light trades—for cutlery, tools, implements, firearms, etc. At that time England, the " workshop of the world," only produced 40,000 tons of steel in a year, of which Sheffield was credited with 35,000 tons. Then came in rapid succession the discoveries of Bessemer, Mushet, Gilchrist, Thomas, the brothers Siemens, and others, and the world was presented with *cheap* steel. The result was that within a single generation mechanical industry, travel, transport, and science made more headway than in all the previous ages combined.

After the demonstration of the Bessemer process (the patent was taken out in 1855) the heavy trades of Sheffield were established and rapidly developed, and the city soon became as famous for heavy armour plate, big guns, rails, and related products as for cutlery and other light articles of steel.

Sheffield has seen the rise of many ambitious imitators and competitors, but it retains its fame and supremacy by reason of the excellence and infinite variety of its products. Apart from mere tonnage, Sheffield is a Pittsburg, an Essen, and a Solingen rolled into one. Sheffield district holds an excellent combination of steel-making resources—the best of fuel, first-class fluxing materials and furnace linings, water with unique properties for tempering and hardening, and

* By E. T. Good.

an inherent artificership and craftsmanship which its younger rivals will find more than difficult to acquire.

Sheffield saw the birth of the famous Huntsman crucible process of making steel of the highest grade for razors, knives, tools, etc., in the eighteenth century. Sheffield witnessed the first practical application of the epoch-marking Bessemer process—the pneumatic conversion process—which brought steel within the economic reach of the ship and railway builder in the nineteenth century. It was Mushet, of Sheffield, who perfected Bessemer steel by the addition of spiegeleisen and manganese. It was the same man who gave us self-hardening steel—a great boon to the engineer. It was in Sheffield that the first "J. B." (John Brown) steel-iron was made into armour-plate. It was the Brown works in Sheffield that produced the first 12-inch-thick plates. It was the Cammell works in Sheffield that made the first "compound" armour-plates. It was the Vickers works in Sheffield that produced the first all-steel armour-plate. It was in Sheffield that Tressider invented the chilling process. It is in Sheffield, more recently, that Sir Robert Hadfield has invented manganese steel, a material which has prolonged the "life" of tram rails, points, crossings, the wearing parts of crushing and other machinery, by something like a thousand per cent., and the equally remarkable low hysteresis steel, which has contributed enormously to the economy and efficiency of electrical plants and apparatus, besides which the same inventor has greatly improved several special steels and alloys. It is in Sheffield also that Mr. Harry Brearley has produced a stainless steel for knives, much to the delight of the housewife, and suitable for a wide variety of commercial and engineering purposes. These steels are more detailed later on.

A feature of the Sheffield works is their laboratories, splendidly equipped, efficiently staffed, and generously supported. Research and experimentation work never ceases. Sheffield is always out to beat its previous best. And the efforts of the various firms are ably backed up by the local university, which is perhaps the most practical industrial and scientific educational institution in existence. Columns might be written about this university, its staff, and its achievements. It is a great asset.

The ancient cutlery trade of Sheffield did not consent to adopt what are called machine methods of mass production until the War. It stuck to handcraftsmanship. It boasted quality rather than quantity. But during the War, to meet the sudden and huge demand for knives, etc., for the Army and Navy, and for the forces of our Allies, the Sheffield cutlery—and also the other light trades—adopted machinery and mass production; but these trades claim that in so doing they have managed to retain all the essentials in processes, quality, and finish which made Sheffield goods world-famous in the old days. The university has given great assistance on the technical side. Works have been remodelled and freshly equipped, the men work under more healthy conditions, and plants can now yield thousands of articles where formerly only dozens were produced.

The edge tool trade has been pre-eminent for quality of product for ages, and now it can turn out quantity as well as quality, for plants have been extended, processes speeded up, new machinery installed, and various firms are operating

in unity so that each may specialize in a particular class of product. Saws of every size, to cut wood, stone, and metal, are produced. Files of seventy kinds are made in this city. Hammers of every sort used by man, from the biggest steam hammer to the smallest one required by the surgical instrument maker, are produced here. Drills, reamers, shears, etc., are turned out to every requirement. Sheffield machine tools maintain an unquestioned supremacy in the engineering world, save, possibly in the case of one or two American specialities.

Wire ropes constitute a special line in Sheffield. There are three big wire rope plants in the city. The wire for these ropes is, of course, a local product of the highest possible strain, tested up to 120 tons per square inch. The heavy wire of Sheffield, like its needle wire and piano wire, stands unrivalled. The wire ropes are used extensively by coal and other mining companies at home and abroad, in gold and other mines in the Dominions and various foreign countries, and on board merchant and naval ships the world over. Wire ropes exceeding 11 miles in length and 31 tons in weight, in single pieces, have been made in the Sheffield works. One of the firms has ten selling establishments in foreign countries.

The silverware and electro-plate industry of Sheffield is another line in which supremacy is well maintained. The silver-plating of table utensils, bridle bits, stirrup irons, and similar things has been carried on in Sheffield from the earliest known times. In 1743 there was a notable discovery by one Thomas Boulsover. This brought about the manufacture of tableware in silver-plated copper, and the products became known all over the world as Sheffield plate. This was followed by the production of similar articles in silver. Since then there have been further improvements, and Sheffield products of silver, silver-plate, electro-plate, nickel, and Britannia metal are works of art and craftsmanship of the highest order.

Crucible steel merits special mention. It is to this kind of steel that Sheffield cutlery and tools own much of their fame. The chief principle of ordinary steel-making is the refining of pig iron, or mixtures of pig iron and scrap iron and steel, by oxidation of impurities—carbon, manganese, and silicon in what are called the acid steel processes, whilst in the basic processes sulphur and phosphorus are also largely eliminated. The oxidizing medium varies in the different processes. In the Bessemer converter the oxygen of the air is made to react direct. In the Siemens-Martin process oxygen is supplied in the solid state as hematite ore (oxide of iron). But in the Huntsman crucible process there is no refining action, the quality depending upon the purity and grade of the raw materials used and the human skill in melting and manipulation. Up to the middle of the eighteenth century all Sheffield steel was of plastic origin, the material never having been in fluid condition. Benjamin Huntsman, a Doncaster clockmaker, was not quite satisfied with the nature of the material he was getting for delicate clock springs, and he began making experiments with a view to obtaining a better quality of steel. That was in 1738. He worked assiduously and secretly. He met with success, and for a full hundred years his process was practically the only one by which steel was produced. It is still the great process by which material for high-grade tools and other light products is made.

Huntsman had a factory built at Attercliffe, Sheffield, in 1770, and had his men sworn to secrecy. Local manufacturers defamed his products for a time, but foreign consumers, less prejudiced, recognized its value, and its reputation spread rapidly. Eventually a local competitor obtained the secret. Disguising himself as a common wayfarer, he presented himself at the works one stormy night, craving shelter and rest. He was admitted and allowed to lie on a cinder heap. He pretended to sleep, but observed the operations, obtained the secret, and got on the road to fortune. The famous process is well described in the words of Henry Seebohm:

"The process of melting is of the utmost importance. The melting furnace consists of a flat stack, containing a flue in each 3 feet (square) or rather less. To each there is a melting hole wide enough to contain two melting pots, and deep enough to allow of sufficient cokes to cover the lids. The top of the melting hole is on a level with the floor of the furnace, the grate bars below being accessible from the cellar. The pots are usually a mixture of Burton or Derby clay, and sometimes Stourbridge clay, Stannington clay, and Devonshire or China clay, with a small addition of cokes and old pots ground. Each pot lasts one day, and is used three times, containing severally about 50, 44, and 38 pounds of steel each 'round.' The bar steel of the exact temper required is first carefully selected, broken up into small pieces, and conveyed to the pot (which has already been placed in the melting hole) through a kind of iron funnel, called a charger. The degree of heat to which the furnace is allowed to go is carefully watched by the 'puller-out,' who is technically said to 'work' the holes, and the exact period at which the steel is ready to be 'teemed' or poured into the ingot mould is noted by the melter. The pots are lifted out of the holes by means of a pair of iron 'pulling-out' tongs. As soon as the lid is removed with the lid tongs, the scum or flux is removed from the surface of the molten steel, which is then poured into a cast-iron ingot mould, formed of two halves, tightly ringed, and wedged together. The interior of the mould has been previously 'reeked' or covered with a coat of coal-tar soot, to prevent the ingot from adhering to the mould."

Since that was written the weight of charge has been increased by some 20 or 25 pounds, and the number of charges, or rounds, has been reduced to two, the working shifts being shorter than formerly. Otherwise the crucible process remains practically unchanged, though progressive firms are constantly striving to improve the product by varying the alloys or by using, whenever possible, better raw materials. This process still stands as the one by which the very highest grades of steel are made, though the modern electric melting furnace challenges the crucible in several lines, and is, of course, more economical, reckoned by the £ s. d. test. The value, not only of the crucible, but of the special Sheffield materials and processes, may be gathered from this fact. During the War the export of high-speed steel was prohibited, but when America came into the struggle our recipes and also instructors were sent to the United States; but since the War, American engineers have reverted to the use of Sheffield material for the highest speed work, notwithstanding the very high tariff imposed by the United States Government.

Of Sheffield crucible steel the late Mr. J. Stephen Jeans wrote, in his *Iron Trade of Great Britain*, that " one of its distinguishing characteristics was the wide range of tempers aimed at and produced, classified according to the percentages of carbon, which ran from ¾ to 1½ per cent. The crucible-steel manufacturer had to produce at least eight different qualities of final product from as many grades of material, each costing a different price. Each of these qualities might be made of seven different tempers, giving fifty-six different kinds of steel, varying in the percentages of metalloid, in temper, and in other conditions. Not only so, but each of these different grades of steel could be produced by four different methods."

Sheffield sells its crucible steel at prices ranging beyond £200 a ton, and in spite of all other processes the firms with the highest reputation make and use this material for the finest cutlery, tools, and instruments. There have been improvements since Mr. Jeans wrote. There have been improvements arising out of the special work and experimentation conducted on account of munitions production during the War. Swedish bar iron remains one of the constituents of best Sheffield crucible steel.

Besides the laboratories of the individual firms, and the famous Sheffield University, there are other agencies making for progress. There is an Association of Metallurgists and Metallurgical Chemists embracing all the scientific men in the local industries; and there are six Sheffield Trades Technical Societies to promote efficiency through specialization and organization within the various groups of industries.

For many generations Sheffield industries were marked by pure individualism. Inventions and discoveries and enterprises were invariably one-man affairs. But within the last twenty-five years or so the emergence of German and American competition, conducted in the former case mainly by specialized methods of manufacture and organized marketing of goods, and in the latter case by modern mass production, developed by huge and financially powerful combines, or corporations, has obliged Sheffield to go in for specialization, combination, and organization as additions to its individual efforts.

The heavy trades were the first to adopt what may be called modern methods. In fact, the heavy trades are of purely modern origin and development. Roughly, Sheffield industries are divided into two classes—the light and the heavy. The light trades are of ancient origin, as already explained. They comprise cutlery, tools, implements, silver and electro-plated ware, etc. The heavy trades, which embrace railway, ship, bridge, and general constructional and engineering industries, were not possible until after the demonstration of the Bessemer process of making cheap steel in the sixties of the last century. From then onwards the growth of works engaged in the heavy lines was rapid. For a long time the light trades merely marked time, and it is questionable whether Sheffield would ever have become a really big city had it not been for the heavy trades. However, since the revolution due to the Bessemer process, plus the Siemens-Martin process, Sheffield has become as famous for its heavy constructional steel, its big guns and huge armour plates, as it is for pocket-knives, table utensils, and engineering tools. For nearly fifty years we saw little or no notable

development in the light trades, but wonderful developments in the heavy lines. Since the outbreak of the big European War in 1914 we have, fortunately, seen great developments in both the light and heavy trades.

It may be said that Sheffield, especially the Sheffield engaged in the production and manufacture of light and special steel products, as apart from the Sheffield engaged in shipbuilding steel and other heavy materials, had been content to rely upon old methods for a long time up to the very end of the nineteenth century, and that about that time it was roused from its lethargy by a challenge from the United States. The American steel industry was making giant strides. Not only was it hugely increasing its productive capacity in the heavy branches, and making the cheapest steel in the world, but just about the beginning of the current century certain American steel-makers and engineers began to create sensations in the metallurgical sphere. For one thing, they produced a tool steel which, it was claimed, equalled Sheffield's best. That acted as a tonic. Sheffield set to work experimenting with tungsten, chromium, manganese, vanadium, and other alloys and ingredients. It trebled the intensity of its heat treatment without sacrificing the hardness of product. Since then it has utilized molybdenum, cobalt, nickel, titanium, and silicon. Sheffield obtains far more per ton for its steel than any other producer. The special steels and steel products of Sheffield get over the highest tariff walls—they carry the heaviest of import duties—and then compete successfully with the products made under the shelter of those walls.

The metallurgists of Sheffield have given us steels that will not corrode, steels that improve with age, steels that will cut or bore any and every steel made elsewhere. Every foreign improvement in armour plate has been followed by a Sheffield projectile to pierce it. Every foreign projectile has been met by a Sheffield plate that would withstand it. High-speed machines the world over are fitted with Sheffield tools, or tools made from Sheffield high-speed steel.

The discovery and invention of manganese steel by Sir Robert Hadfield, of Sheffield, was not only a great thing in itself, increasing the life of wearing parts of machinery and other things by about 1,000 per cent., but it opened out a fresh avenue of metallurgical research. It marked the first practical development in what are known as ferrous alloys. Numerous steel improvements quickly followed the invention of manganese steel. Without these alloy steels the high efficiency motor-car of to-day would be an impossibility. So would our light and speedy aircraft. This manganese steel in spite of the high iron content is practically non-magnetic, and this quality rendered it of immense service during the War.

Another Hadfield product which is adding to Sheffield's fame is low hysteresis steel. With the heat treatment invented by Hadfield, this steel has some remarkable properties. It is of special value to the electrical engineer. Under low magnetizing forces the material is even more magnetic than iron itself, and it largely reduces the waste of energy previously met with, whether from hysteresis losses or eddy current losses. Low hysteresis steel possesses also the valuable property of not ageing, in fact actually improves with service. It is used chiefly in the construction of transformers and other electrical apparatus. Half a million tons of

this steel have been made, from which transformers with a capacity of about 120 millions K.V.A. have been produced. The first of these transformers was supplied to the Sheffield Corporation in 1905. A conservative estimate places the saving in coal alone effected by low hysteresis steel at 5,000,000 tons a year, or over £7,000,000. This is apart from the saving in copper required in the construction of the new type of transformer, and the smaller space occupied. The old transformer material aged so rapidly that the energy losses were heavy. The new material improves with use.

Dealing with this invention of Sir Robert Hadfield, Dr. T. D. Yensen, the prominent American scientist of the Research Laboratory of the Westinghouse Electric Company, estimated, a few years ago, that the total saving effected to the world by this material in reducing energy losses, saving in copper, better apparatus, and other advantages, amounted to no less than £80,000,000—" nearly enough to build the Panama Canal," declared Dr. Yensen. The figure may now be put at £100,000,000.

There are two main factors in Sheffield steel supremacy. One is the quality of the material. The other is the skill in manufacture. The steel-maker used to be satisfied when he had produced a good material in the crucible; something that pleased the cutlery manufacturer, or the maker of bayonets. But nowadays the steel-maker offers anything and everything that the engineer or the scientific instrument maker requires. Armour plates were a great line that gave a new fame to Sheffield. They are now but a side line. Rails gave Sheffield another claim to fame, as they gave the world cheap travel and rapid transport. Now Sheffield is famous for its railway engines and carriages. Sheffield produces tramway points and crossings, and various other things that have to stand friction, and here the wonderful manganese steel steps in and almost defies wear.

Dozens of works in Sheffield produce various brands of high-grade steel which are triumphs of science. Every big works has its laboratory. Every known chemical and physical test is applied. Dr. Albert Sauveur, Professor of Metallurgy at Harvard University, has borne eloquent testimony to what he has termed the " steel wizards " of Sheffield. He has reminded Americans especially of what they owe to England and Sheffield. He has explained that by " steel wizards " he means those men who have contributed the great basic inventions upon which the iron and steel industry is founded: men like Huntsman, Cort, Bessemer, and Sorby—men whose discoveries and inventions are epoch-making. He has asked, " Is it not true that, if the contributions of English metallurgists were withdrawn, the entire manufacture of iron and steel would ignominiously collapse ? We would have neither puddling furnaces, nor crucible steel, nor open-hearth steel, nor rolling or forging appliances, but for English inventions. America makes more pig iron than any other country, but the blast furnace was neither invented nor developed in the United States. That expensive fuel, charcoal, has been discarded through the invention of an Englishman, Dudley, in 1619. America makes more coke than any other country. Coke was first made and used by Darby, another Englishman, in 1735. It was Neilson, of Glasgow, who first used the hot blast. It was Budd, an Englishman, who first suggested the burning

of waste gases. It was Taylor, of England, who, in 1840, suggested the closing of the top of the furnaces. It was Parry, an Englishman, who invented the bell hopper or cup and cone in 1850. It was Cowper, an Englishman, who invented regenerative brick stoves in 1860. America makes more wrought iron than any other country, but the wet puddling furnace was invented in England in 1784 by Henry Cort, and improved in the same country by Hall and Rodgers about 1830. America has an important crucible steel industry, but it was Huntsman who invented, in 1740, the method still followed; and Mushet, another Englishman, who improved crucible steel in Sheffield in 1801."

America, Dr. Sauveur reminds us, makes more Bessemer steel than any other country, but Bessemer was an Englishman and demonstrated his invention in Sheffield. In Sheffield also Mushet added the wonderful spiegeleisen to steel. The basic Bessemer process was perfected by Gilchrist and Thomas, two Englishmen, who were cousins.

Turning to rolling mills and forges, we have been reminded by Dr. Sauveur that the two-high pull-over grooved mill was invented by Cort, and the reversing mill by Ramsbottom, in England, in 1866; that the continuous mill was invented by White, an Englishman; that the steam hammer was invented by two Englishmen, Watts and Nasmyth; that the hydraulic process was invented by two Englishmen, Bessemer and Gledhill; that the first tilting open-hearth furnace was invented by Campbell, and so on. The best of all these are concentrated in Sheffield.

Sheffield has produced soft basic steel as low as £4 10s. a ton, and sells high-grade material at £280 per ton for making scientific instruments.

Wireless telegraphy owes much to Sheffield, for this city has produced the necessary material and made the proper apparatus. Magnets for electric meters; all the special parts for aeroplanes and their engines; the finest drawn wire for all purposes; the exact materials and the furnishings for the submarine, for naval and field guns, for projectiles, for turbines, wire for torpedo nets, saws that will cut cold metal as well as timber, and all kinds of tools—hand, machine, and high-speed tools—are made here.

What is claimed to be an ideal steel has recently been invented in Sheffield, and this may almost be described as the crowning point in ages of investigation, invention, and industry. This is the rustless or stainless steel mentioned earlier. Mr. Harry Brearley discovered the method of rendering steel rustless without impairing its ordinary qualities in 1912-13. Now the leading Sheffield manufacturers supply the material and its products, and there has been a well-sustained demand for rustless steel goods right through the deep trade depression recently suffered by other branches of industry. A great future is predicted for this material. When first produced, rustless steel was confined to the manufacture of cutlery, chiefly table knives. As the war was prolonged, the material was reserved for munition purposes. Since the war it has been applied to a variety of uses, and the range is widening. The structure of the steel is first made uniform by correct heat-treatment, a process in which Sheffield specializes. This treatment, coupled with the added alloy in due proportion and by the right method, renders the steel insoluble, and therefore rustless and stainless, in water, alkalies, salt solutions,

fruit juices, some mineral acids, and most organic acids. This steel is soluble in sulphuric and hydrochloric acids. Its use for domestic purposes has come to be very highly appreciated. Knives, for example, retain their original brightness and smoothness indefinitely, and under all conditions.

It is, however, in the field of industrial purposes where this rustless steel is likely to find the most scope. Steel, which engineers use on account of its great tensile strength and toughness, is soluble in water; its solubility is certainly slight, and it may be of small consequence for many purposes; but it is a great disadvantage in steel used for hydraulic work. Wrought iron will rust in water without being in contact with air. The iron dissolves slightly. Exposed only to ordinary weather conditions iron corrodes. In clean, dry climates the rate of corrosion is slow, but it is fairly rapid in wet climates. Steel rusts like iron because it is directly soluble in water, but it corrodes more vigorously because it is a conglomerate substance, iron being, of course, a simple substance. The constituents of ordinary steel dissolve at different rates, and the material becomes pitted as well as rusted. It is here that the merit of the new rustless steel comes in. The material retains all the good properties of ordinary steel—tensile strength, toughness, and so forth; but, in addition, it has the wonderful property of being rustless and stainless. It will not corrode or dissolve in the least degree. A great future is promised for it in such uses as pumps and presses, dredgers and crushers, mining purposes, motor-cars and aircraft, refrigerators, valves, piston rods, etc. Various things made of ordinary steel, which have worn out in from three to twelve months, have been replaced with rustless steel products, and these are still working after two and three years' service, with every evidence of long life yet.

A notable recent development of Sheffield industry is the establishment of Trade Technical Societies. Prior to 1918 there had been a gap between the research and the labour sides of industry. Many workmen performed their tasks mechanically, with little appreciation of the why and wherefore of the processes of manufacture, whilst men in the research laboratories often lacked knowledge of certain practical working details.

Professor Ripper (just retiring), the extremely able and earnest man who has been the soul of much of Sheffield's research at the University end, saw both sides of this gap. The intelligence of the rank and file was to some extent running to waste, and he planned to divert it into the branches where scientific knowledge was pursuing a sort of splendid isolation. In short, he planned a link between industry and the University.

The outcome was that in 1918 began the formation of Sheffield Trades Technical Societies. These now represent the following industries: (1) Cutlery; (2) files; (3) silver; (4) edge tool, machine knife, and saw; (5) foundry; and (6) rolling, tilting, and forging.

The societies elect annually their own officers and council, and they receive help in organizing their movement from the Department of Applied Science at the University. The responsibility for lectures, discussions, and research work undertaken for a trade rests with that trade, and all sections of the trade are represented on the councils, so that there is always a governing body of practical

and experienced men directing the attention of that trade to the problems and inquiries arising from the lectures.

At least once a month meetings are held at the University, and thus the workers in each industry, through their chosen representatives, have at close hand the conveniences for scientific and technical research into any problem they have raised. Each trade is kept in the limelight so that it can see its own way about and maintain up-to-dateness. If Sheffield was able to retain its old supremacy in the steel trade under the antiquated conditions that governed some of its industries before the great European War, it is much more likely to retain it in the future with a connecting-link such as the Technical Trades Societies provide. The idea of mobilizing brawn and brain in a single forward movement was excellent in its conception, and promises a hopeful and solid development for Sheffield trade as soon as economic conditions have shaped again towards the normal.

Regarding markets for Sheffield products, it may truly be said that their limits are those only of the world, whilst it may justly be claimed that no city or industrial district sends out a greater variety of steel goods. Poverty of buyers and abnormally adverse exchanges since the War have seriously circumscribed the Continental European markets since the Great War; but when financial and political matters are anything like smoothed out, Europe, with its 420,000,000 inhabitants, will buy more Sheffield goods, German competition notwithstanding. In the Near East, in Italy, Austria, Spain, and Finland, trade is opening out, especially for railway steel and equipment. The best markets of the world for Sheffield railway materials and rolling stock are India and the chief Latin-American Republics. South Africa and Australia are also good customers. Sheffield-made mining equipment and appliances are in demand in India, Canada, Australia, South Africa, Japan, and China. Sheffield electrical appliances, power plant equipment, dock cranes, derricks, and dredging apparatus are employed and are in progressive demand in all the leading South American and Far Eastern countries, and the British Dominions. Sheffield tools, implements, and cutlery and plated ware find their best overseas markets in Australia, Canada, India, and two or three of the South American countries. Within the four corners of Britain railway companies, shipbuilders, marine engineers, general machinery makers, textile engineers, colliery proprietors, and house builders are Sheffield's best customers, in about this order, for heavy, medium, and light products, whilst cutlery and plated goods, lines to themselves, are supplied to nearly all hotels and shipping companies, not to mention householders.

Sheffield merits a special word about its work during the Great War. The history of the Sheffield trades prior to the War was an industrial romance, spiced with dramatic discoveries and developments. During the War, Sheffield performed wonders. Since the War it has greatly increased its productive capacity, further perfected its processes, products, and organization; and when political and financial difficulties are smoothed, and the trade of this part of the world opens out properly, Sheffield will astonish both customers and competitors by the volume, value, and variety of its goods. The extensions and experiments

effected during, and in consequence of, the War, will bear fruit in the coming years of peace. Regarding the war and the tremendous demand for munitions, it may be observed that the quality of steel is no less important in war than the strategy of generals or the bravery of troops. To the making of munitions Sheffield brought the accumulated results of centuries of experience in the production and manufacture of iron and steel. The capacity of Sheffield armament works was one of the decisive factors in the War. Sheffield out-Krupped Krupps. Within a few months prodigious quantities of munitions were turned out for the Allied armies and navies. Amazing inventions in guns, in armour, in shields, in aircraft, and submarine materials and equipment were made in Sheffield. Most of the plants, the extensions, the skill, the improved knowledge, are now available for the production of commercial products. The purchaser of steel and steel goods can be accommodated in Sheffield with every known product, made from steel produced by every known process. For every class of heavy forging and casting, for marine and general engineering work, for the most gigantic presses and forging plants, for the most complete equipment for railways and docks, forges and rolling mills, mines and ships, for power plants of every kind—steam, electrical, water, hydraulic—for bridge and general construction work, for dredging and crushing and conveying plants and apparatus right down to penknives and musical wire, customers may rely upon Sheffield for what they require in quality and design.

CHAPTER IX

*TINPLATES**

It is perhaps unnecessary at this date to explain that " tinplate " is really an abbreviation of " tinned plate," and that the " tins " with which we are so familiar are made, not with tin, but from thin sheets of steel, coated with a film of tin, the steel for strength and the tin for protection. From the multiplicity of uses to which tinplate is put, it is not surprising that the tinplate industry is a very large consumer of steel. The industry is now almost entirely confined to South Wales, where there are 77 works operating 503 mills. P. W. Flower, in his *Origin and Progress of the Work of Tinplates*, states that " the manufacture of tinplates dates back to a period which is beyond the records of metallurgical history, but the trade is known to have been of German origin and to have existed in Bohemia for many years prior to 1620." At this early date the sheets would, of course, be of iron. The secret of the process was brought to England about 1670, and works were started in 1673. These, however, failed, but in 1720 the industry was successfully established in Wales, and by 1776 the export trade in tinplates began.

* The greater part of this chapter has been contributed by Sir Edgar Jones, K.B.E.; acknowledgments are also due to Mr. H. Spence Thomas and Mr. Henry Clement.

The following table illustrates the growth of the industry from 1750 onwards:

	1750.	1850.	1865.	1891.		1912.		1924.	
	Number of Works.	*Number of Works.*	*Number of Works.*	*Number of Works.*	*Number of Mills.*	*Number of Works.*	*Number of Mills.*	*Number of Works.*	*Number of Mills.*
Glamorganshire	—	8	15	51	277	55	371	48	318
Monmouthshire	2	11	12	15	86	9	56	11	56
Carmarthenshire	2	3	5	20	119	17	128	17	126
Staffordshire ..	—	7	8	4	10	1	5	4	22
Worcestershire ..	—	2	3	2	7	—	—	—	—
Gloucestershire ..	—	3	4	3	17	2	14	2	14
Scotland	—	—	1	—	—	—	—	—	—
Flintshire ..	—	—	—	1	4	1	4	1	4
Cumberland ..	—	1	1	1	2	—	—	—	—
Breconshire ..	—	—	—	1	3	1	3	1	3
Total ..	4	35	49	98	525	86	581	84	543

In non-technical language, the process by which steel bars are transformed to Welsh tinplate may be thus described.

Artisans who have undergone a long period of training to fit them for their task work in conjunction with the most modern and ingenious machinery to produce the world-famous Welsh tinplate.

The process can be described in a few words. Bars of steel, 7 to 10 inches wide by $\frac{3}{8}$ to $\frac{5}{8}$ inch thick, and about 20 inches long, are heated to redness in furnaces, and then passed in and out of rollers, and so flattened and lengthened. They are then reheated, doubled over and rolled, doubled over and rolled again and again, until the required thickness has been attained.

The bars have now become batches of steel sheets, which are next sheared, separated, and "pickled." "Pickling" means cleaning by immersion, first in acid, then in water. They have then to be reheated, or "annealed" (as the process is called) in sealed iron boxes to soften them, and to remove "pickling" stains. The sheets, now cold, are again passed through rollers under great pressure, the object being to produce a good surface. This rolling makes the sheets hard and rigid, so once more they are reheated or "annealed" to restore softness and pliability.

After a second cleansing or "pickling" similar to the first, the sheets are ready to receive the protecting coat of tin. The protection is achieved by passing each sheet separately through molten tin and palm oil, and then on through machinery, which cleans and brightens what has now become Welsh tinplate.

A careful examination of each sheet follows. Any sheet which has the suggestion of a flaw is immediately rejected. Many tinplates which would readily satisfy other experts are promptly thrown aside by the hypercritical Welsh examiners, who are actuated by only one motive—the laudable desire to preserve untarnished the great reputation which Welsh tinplate has won for itself through its intrinsic merit. The prime plates are now ready for dispatch to everywhere—to places near home, to the ends of the earth.

The excellence of Welsh tinplate is due to a number of factors, the chief of which are the efficiency of the machinery used in its production, the quality of the raw materials used, and the skill of the worker. All the best mechanical inventions are attracted to Wales, and the last fifty years have shown great changes in the manufacture of tinplate, from the application of rolls to the grease-pot in tinning machines, whereby a brighter and more evenly coated surface was produced by a smaller consumption of tin (invented by Mr. Morwood), to the latest Melingriffith "pot" invented by Messrs. Thomas and Davis.

With regard to the materials used, not only are the Welsh manufacturers careful to use only the highest quality steel bars in the making of tinplate, but care has also to be exercised in the selection of the tin.

The purity and quality of the natural tin used in the manufacture of tinplates is of great importance. The Health Authorities of many countries have found it necessary to make a regulation that the tin shall be chemically free from arsenic, and the minuteness of the percentage of even a trace of arsenic is so small that the tin has to be practically chemically free. It is not, therefore, desirable for the tin produced from the mines in certain parts of the world to be used for the packing of food, because there is the risk of the presence of arsenic. Fortunately the supplies of the British Empire provide a tin that is free of arsenic, and this is the tin used by the Welsh tinplate makers. There is, therefore, a guarantee of absolute safety in Welsh tinplate for the package of foods.

In this connection it is of interest to recall the fact that attempts at courting with other metals have proved failures because of the different rate of expansion to temperature between the steel plate and the coating.

Tin is ideally adapted to meet this physical effect, and its supremacy therefore remains unchallenged.

But more is required than good machinery and the best materials; imperfect handling will spoil both machinery and materials, and it is the skill of the tinplate worker that carries the promise to fruition. The present-day Welsh tinplate worker is the skilful product of two centuries, during which he or his ancestors have been practising and improving their art. At the factories, controlling the rolls, cleansing, tinning, and examining, are the Welsh operatives, who bring to bear all the knowledge and skill acquired and practised from generation to generation. A Welsh operative knows what is required to make his part of the process perfect; it is as nearly as possible instinctive.

The Great War marked an epoch in the history of tinplate manufacture. The colossal armies of the Armageddon were kept secure from the most devastating of all forms of destruction manifested in past wars—namely, destruction by disease. The horrors of the Crimean War, or even the Franco-Prussian War, or even the much more recent South African War, created by widespread disease, are still well enough known to point the significant contrast of the absence of such decimating disease in the Great War. It is doubtful whether the medical and sanitary officers could have achieved such a result without the aid of tinplate. The tin container distributed foods with plenty of variety that is essential for maintaining health, and in particular distributed green vegetables and milk in

a form that was most convenient for transport, proof against rough usage, and secure in its preserving efficiency.

In an address on the subject of food botulism delivered by Sir William Wilcox, K.C.I.E., C.B., etc., to members of the Provision and Canned Goods Trade Sections of the London Chamber of Commerce, he said: " I never (it would have been brought to my notice if cases had occurred), during the War, saw a single case of food poisoning where the poisoning had arisen from the food being poisonous when it was in the unopened tin. We had close on half a million troops in Mesopotamia—Indian, British, and the Labour Corps, and accessory troops—and I can honestly say that not a single case was brought to my attention. I think this was remarkable, especially in countries where the conditions were most favourable for food poisoning.

" I wrote to my friend General Sir William Macpherson, the editor of *The Medical History of the War*, and I said: ' I have had no personal knowledge of cases of food poisoning from tinned foods; will you tell me something about what happened in France because I think it is so uncommon ?' He wrote back to me—I have his letter in my hand—and said: ' You are quite correct in saying that there were very few cases during the War of food poisoning from tinned foods. The only cases I can trace are three,' and then he very kindly gave me an account of three epidemics which occurred in France. I also saw General W. W. Beveridge, the Director of Hygiene at the War Office, and discussed this matter of food poisoning with him. He also said: ' You are quite right. Food poisoning from tinned foods was uncommon during the War, except when the tinned food had been contaminated during the process of subsequent preparation,' and he gave me an additional fourth case.

" Well now, I investigated the reports of these four cases of food poisoning in the War, three in France and one in Port Said. The three in France were all due to contamination of the good, wholesome tinned food by carriers in the process of making this food up into pies and stews. Two of them were due to the *Bacillus aertrycke*, and one was due to the *Bacillus enteritidis* of Gaertner. The fourth epidemic, the one which occurred at Port Said, was due to the contamination of wholesome tinned milk, the contents having been emptied into a cauldron and then allowed to stand in that warm climate, a carrier probably having to do with the mixing of the milk. It was due to an infection from a carrier of the *Bacillus aertrycke* that this epidemic of food poisoning occurred. So there, gentlemen, you have the analysis of that great experiment—the greatest experiment in history—the feeding of many millions of troops for years on tinned foods, and the evidence as to the tinned food being poisonous was practically nil. It is a very marvellous example. I do not believe, gentlemen, that public attention has been called to that before."

Dr. Gerald R. Leighton, the Medical Officer who investigated the deaths of eight persons from botulism at Loch Maree in 1922, came to the conclusion that the tin container had every advantage over the glass one as a vehicle of preserved foods, because " it is common experience in the trade that the glass container cannot be heated above boiling-point without the risk of a good many being broken. Sterilization of glass containers, therefore, at such a temperature

as would be certain to destroy certain pathological spores would not appear to be a sound commercial proposition."

During the War millions of men who had never before become accustomed to canned foods learned to appreciate them. The result of this is to be seen in the enormous increase of consumption of canned foods amongst the European nations, and in India and Japan. This increase is very extraordinary in relation to milk. The conversion of the people of different nations to consume canned products has reflected itself in the conversion of the growers of products to resort to canning. The first thought of farmers in the United States of America when they turn their land to the production of fruit or vegetables, or their coasts to the catching of fish, is to combine with neighbours or capitalists for the erection of factories for canning produce. It is only in that way that they can be sure of the preservation of their crop from deterioration, and of transporting it to markets where value for it can be obtained. Canada has benefited by the example of her neighbour, and is making great strides in the canning of products. It is not only salmon and "bully" beef now as it used to be, but lobsters, fruits, vegetables, and milk. Australia has discovered that her only means of developing her fruit-growing resources is by using the tin container to carry produce to distant markets. In almost every other part of the Empire new canning factories are constantly being established for the purpose of developing the possibilities in the soil and the climate. The older countries of Europe have been far behind America in the art of canning, but, as has been said, the War has given a great impetus that is leading to a steady expansion.

Blackplates and Terneplates.

A Welsh blackplate is exactly the same as a Welsh tinplate, except that its manufacture has been stopped before the second cleansing (or "pickling"). It has, therefore, all the excellent characteristics of a Welsh tinplate (except the protecting ones imparted by the skin of tin), and consequently is in great demand. Certain countries, finding it impossible to produce the special steel necessary to make a good tinplate, import blackplate from Wales, and do their own tinning. The motor-car industry, wherever it is pursued, makes great demands on Wales for blackplates and terneplates, which latter are steel sheets coated with a mixture of tin and lead. Strength with little weight is essential to a good car, and Welsh blackplates and terneplates are wonderfully light compared with their strength. For similar reasons extensive use is made of terneplates for roofing purposes, the addition of a coat of paint making a strong, light, weatherproof and attractive cover to buildings. Drums for oils, paints, varnishes, and chemicals are best when made from Welsh terneplates, the coating of lead and tin, besides rendering complete protection, making soldering a very simple process. A very interesting use for blackplate is that of stamping out ornamental panels for walls and ceilings. Very beautiful designs are possible, and use of this type of decoration is growing.

Enamelware.

The service to which blackplate is put, that will most appeal to the ordinary person, is that of a basis for enamelled hollow ware. It may not be known that underneath the clean, hard, attractive surface of the domestic enamelled saucepan, and similar articles, is this ubiquitous Welsh product.

Owing to its capacity for being easily and quickly cleansed, enamelled ware has become increasingly popular, there being few modern households which have not some article made of it. Its use has the sanction of the medical profession, in that a vast number of surgical, sanitary, and medical accessories are made of it, and are in daily use in hospitals and sick-rooms in every country.

The progress of the industry suffered a severe setback in 1889 when the United States, at that time our best customer, decided to become independent of the British manufacturers by creating a tinplate industry of her own. This she did by erecting a high tariff wall upon all importations of tinplate, which became effective in 1891. The effect upon our export trade to America is seen in the following figures:

1879	155,595 tons.	1912	2,135 tons.
1889	336,689 „	1919	254 „
1899	63,546 „	1923	9,680 „
1909	64,446 „		

It is not possible, however, to reproduce, without a long struggle beset with many difficulties, the combination of knowledge, organization, and skilled workmen that must be effectively achieved in this difficult art. Wherever measures of high artificial protection are resorted to in order that new local works may be fostered it inevitably means many years of higher prices for inferior products as a charge upon the canning factories and the producers who grow the products.

That the export of tinplates is very widespread is sufficiently indicated by the figures on p. 115, which compare exports of tinplates in 1912 and 1913 with those of 1922 and 1923, and shows that the export trade in tinplates is now actually higher than before the War, although there has naturally been some changes in the different markets.

The Welsh makers turn out a great variety of plates in order to meet the requirements of various types of consumers. It might be more immediately profitable to endeavour to force the standardization of a few definite varieties, but that has not been the policy of the Welsh makers. They are always seeking to comply, so far as possible, with the needs of the consumers. They are able to pursue such a policy, and to do so at prices that compete favourably with the producers in other countries. This is made possible because their works and organization have been developed gradually over a long period of years, and their machinery, plant, and works stand at very low values in their capital account. The result of that is that they can secure a fair return on their capital at prices that new ventures starting up to-day could not work to.

EXPORTS OF TINPLATES FROM THE UNITED KINGDOM IN 1912, 1913, 1922, AND 1923 (TONS).

	1912.	1913.	1922.	1923.
India and Ceylon	39,952	51,571	39,850	58,908
Egypt	5,213	5,871	6,755	8,829
South Africa	2,640	2,559	3,460	5,494
Canada	7,297	9,889	41,896	27,319
Australia	29,201	28,961	37,717	42,369
New Zealand	4,107	4,241	3,680	5,110
Other British Possessions	17,558	19,362	17,549	2,916
Total	105,968	122,454	150,907	150,945
Norway	31,503	25,166	16,862	19,114
Sweden	7,264	7,660	8,109	7,595
Denmark	6,384	5,312	9,801	14,159
Germany	41,379	34,739	18,051	22,782
Netherlands	44,156	43,009	30,059	36,239
Belgium	18,875	13,363	19,177	22,568
France	31,930	21,332	32,232	38,003
Switzerland	10,415	7,641	1,432	3,433
Portugal	15,797	14,873	16,799	19,248
Spain	9,049	12,295	20,520	16,520
Italy	21,478	20,418	16,083	19,029
Rumania	35,920	10,927	7,016	5,270
Greece	—	—	2,094	1,999
China	9,152	15,569	10,208	29,554
Japan	23,236	28,222	17,285	37,658
Chile	—	—	663	3,161
Brazil	9,721	14,414	8,676	17,161
Argentine	10,283	19,323	17,775	27,023
Other South America	4,347	5,459	2,223	2,785
United States of America	2,135	21,516	3,011	9,680
Other foreign countries	42,131	50,805	40,290	47,201
Total	375,155	372,043	298,366	400,182
Grand total (tons)	481,123	494,497	449,273	551,127
Value (£)	6,833,292	7,214,988	9,705,471	12,601,409

TECHNICAL HINTS TO PURCHASERS OF TINPLATES.

The foregoing pages are addressed to the general interest as much as to the commercial. The following are specially directed to those who, by using or distributing Welsh tinplate, have a more intimate connection with the industry. The previous pages will, it is hoped, not be without interest to those so connected; they may possibly make the handling of Welsh tinplate a somewhat less prosaic occupation by indicating the romance surrounding the product.

Tinplates (and, of course, blackplates and terneplates) are manufactured in a variety of sizes and gauges, many of which are standard; but, within limits, sizes and gauges can be manufactured to suit customers' requirements.

All measurements and prices are based on the area of the standard box of tinplate, 20 by 14 inches, 112 sheets, which is equal to 31,360 superficial inches weighing net 108 pounds. These are called I.C.

Plates thinner than I.C. are called lights. The variations most usual are 100 pounds and downwards in gradations of 5 pounds per box.

Plates thicker than I.C. are called crosses. The following are the equivalent weights (basis 20 by 14 inches, 112 sheets, 108 pounds):

I.X.L.	= 122 pounds.
I.X.	= 136 "
I.X.X.	= 156 "
I.X.X.X.	= 176 "
I.X.X.X.X.	= 196 "

Odd sizes have to be manufactured from tinplate bars, specially rolled according to the size and thickness of the sheets to be produced. Consequently, the cost of these odd sizes depends on several conditions—their suitability for manufacture, output from the mills, and so on. Moreover, it is not always possible to produce exact quantities ordered in odd sizes, and wasters—*i.e.*, imperfect sheets—arise in varying proportions during manufacture, and buyers usually accept these with the primes at a reduction per basis box. Certain sizes, thicknesses (or substances) are usual for certain purposes, and, in the hope that they may prove useful, a few are indicated below.

It is sometimes advantageous for users of tinplates for food packing, and for other purposes, in a large way of business, to have supplies in such special sizes as will enable an exact number of tins or parts of tins to be cut without scrap or waste. These the Welsh manufacturers are ready to supply, and it is usually found that the small extra cost is more than saved by there being no waste. But it should be borne in mind, when selecting special sizes, that lengths varying from 27 to 30 inches, and widths from 18 to 22 inches, are most suitable and economical to manufacture.

When ordering special sizes, state:

1. Thickness.
2. Number of sheets and weight per box.
3. Size.

Or if (1) and (2) are not ascertainable, then the equivalent weight per box of 20 by 14 inches, or 28 by 20 inches, 112 sheets, should be given.

Where articles or containers of a deep character, stamped, or drawn on automatic machines, are to be manufactured, specially suitable Welsh plates should be ordered to ensure satisfactory results. It is advisable, when ordering tinplates destined to be subjected to the strains involved in deep drawing, to state for what purpose they are required, as by so doing the experience of the Welsh manufacturers will be placed at the user's disposal to provide what is most suitable.

For conserving perishable food of all kinds—meat, fish, vegetables, fruits—whether for packing raw or cooked, in cans under heat or steam pressure at proper

temperature, coke tinplates (or alternatively for certain fruits and vegetables —lacquered tinplates):

I.X., 20 by 14 inches,	112 sheets,	136 pounds	.. .. ..	B.G. 28·0
I.C., ,,	,,	108 ,,	.. ..	B.G. 29·9
,, ,,	,,	100 ,,	.. ..	B.G. 30·6
,, ,,	,,	95 ,,	.. ..	B.G. 31·1
,, ,,	,,	90 ,,	.. ..	B.G. 31·6
,, ,,	,,	85 ,,	.. ..	B.G. 32·0
,, ,,	,,	80 ,,	.. ..	B.G. 32·5
I.C., 28 by 20 inches	,,	216 ,,	.. ..	B.G. 29·9
,, ,,	,,	200 ,,	.. ..	B.G. 30·6
,, ,,	,,	190 ,,	.. ..	B.G. 31·1
,, ,,	,,	180 ,,	.. ..	B.G. 31·6
,, ,,	,,	170 ,,	.. ..	B.G. 32·0
,, ,,	,,	160 ,,	.. ..	B.G. 32·5

B.G.=Birmingham Gauge.

For packing petroleum, kerosene, petrol, and other oils and liquids:

I.C., 18¾ by 14 inches, 124 sheets to box weighing 110 pounds	B.G. 30·0
I.C., 20 by 10 inches, 225 sheets to box weighing 156 pounds	B.G. 30·0

Two sheets of the first are used to make the four sides of a case holding nominally 2 gallons of kerosene, and one sheet of the second, cut in half for top and bottom.

Subject to the note above regarding special sizes, manufacturers find the standard sizes suitable for packing the following classes of goods, the B.G. (substance) being indicated:

All kinds of biscuits, sweetmeats, dry goods ..	B.G. 30·0, 30·6, 31·0, 31·5, 33·0
Toilet, beauty, and pharmaceutical requisites ..	B.G. 30·0, 31·0, 32·0, 33·0
Boot, metal, stove, and other polishes	B.G. 30·0, 31·0
Tobacco and cigarettes	B.G. 30·0, 31·5

(For air-tight tins a specially thin sheet of 37·5 B.G. is used for the top inside, the outer lid being fitted with a cutter.)

The following list of articles requires the standard (or special) sizes with B.G. (thickness) stated:

Advertisements	B.G. 28·0, 30·0, 31·0
Fancy trays	B.G. 27·0
Toys	B.G. 30·0, 31·0, 32·0
Buttons	B.G. 31·0, 32·0
Necks and screw stoppers	B.G. 30·0
Steel ceilings	B.G. 28·0
Deed boxes and cash boxes	B.G. 28·0

STANDARD WEIGHTS AND SIZES OF TINPLATES.

Birmingham Gauge.	*Substance.* *Lbs.*	*Substance.* *Millimetres.*	*Size.* *Ins.*	*Size.* *Millimetres.*	*Number of Sheets per Box.*	*Net Weight per Box.* *Lbs.*	*Net Weight per Box.* *Kilos.*	*Gross Weight per Box.* *Lbs.*	*Gross Weight per Box.* *Kilos.*
35·7	55	0·160	20 by 14	355 by 508	112	55	25	60	27
35·0	60	0·175	,,	,,	,,	60	27	65	30
34·2	65	0·191	,,	,,	,,	65	30	70	32
33·7	70	0·203	,,	,,	,,	70	32	75	34
33·1	75	0·218	,,	,,	,,	75	34	80	36
32·5	80	0·234	,,	,,	,,	80	36	85	39
32·0	85	0·249	,,	,,	,,	85	39	90	41
31·6	90	0·262	,,	,,	,,	90	41	95	43
31·1	95	0·277	,,	,,	,,	95	43	100	45
30·6	100	0·290	,,	,,	,,	100	45	105	47
29·9 I.C.	108	0·315	,,	,,	,,	108	49	113	51
28·0 I.X.	136	0·397	,,	,,	,,	136	62	141	64
26·8 I.X.X.	156	0·454	,,	,,	,,	156	71	161	73
25·8 I.X.X.X.	176	0·511	,,	,,	,,	176	80	181	82
24·8 X.X.X.X.	196	0·574	,,	,,	,,	196	89	201	91
35·7	55	0·160	28 by 20	710 by 510	,,	110	50	120	54
35·0	60	0·175	,,	,,	,,	120	54	130	59
34·2	65	0·191	,,	,,	,,	130	60	140	64
33·7	70	0·203	,,	,,	,,	140	64	150	68
33·1	75	0·218	,,	,,	,,	150	68	160	72
32·5	80	0·234	,,	,,	,,	160	72	170	78
32·0	85	0·249	,,	,,	,,	170	78	180	82
31·6	90	0·262	,,	,,	,,	180	82	190	86
31·1	95	0·277	,,	,,	,,	190	86	200	90
30·6	100	0·290	,,	,,	,,	200	90	210	96
29·9 I.C.	108	0·315	,,	,,	,,	216	98	226	103
28·0 I.X.	136	0·397	,,	,,	56	136	62	146	66
26·8 I.X.X.	156	0·454	,,	,,	,,	156	71	166	75
25·8 I.X.X.X.	176	0·511	,,	,,	,,	176	80	186	84
24·8 X.X.X.X.	196	0·574	,,	,,	,,	196	89	206	94
33·9	68	0·198	30 by 21	760 by 530	112	153	70	165	75
33·0	76	0·221	,,	,,	,,	171	78	183	83
32·3	83	0·241	,,	,,	,,	184	84	196	89
31·0	96	0·279	,,	,,	,,	214	97	226	102
29·9 I.C.	108	0·315	,,	,,	,,	243	110	255	116
28·0 I.X.	136	0·397	,,	,,	56	153	70	165	75
26·8 I.X.X.	156	0·454	,,	,,	,,	176	80	188	85
25·8 I.X.X.X.	177	0·511	,,	,,	,,	198	90	210	95
24·8 X.X.X.X.	195/6	0·574	,,	,,	,,	220	100	232	105
31·8	87	0·254	18¾ by 14	355 by 476	124	90	41	96	44
31·5	91	0·264	,,	,,	,,	95	43	101	46
31·0	96/97	0·279	,,	,,	,,	100	45	106	48
30·1 I.C.	106	0·310	,,	,,	,,	110	50	116	53
28·0 I.X.	135	0·394	,,	,,	,,	140	64	146	67
31·6	89½	0·262	20 by 10	254 by 508	225	128	58	134	61
30.6	100	0·290	,,	,,	,,	143	65	149	68
31·1	95	0·277	,,	,,	,,	136	62	142	65
29·0 I.X.L.	121	0·353	,,	,,	,,	174	79	180	82
28·0 I.X.	136	0·397	,,	,,	,,	195	89	201	92
29·9 I.C.	108	0·315	,,	,,	,,	156	71	163	74

CHAPTER X

*SHEETS**

LITTLE information is available regarding the early development of sheet manufacture in this country. A process of sheet-rolling appears to have been introduced into this country over 200 years ago, though it was not until 1728, when John Payne invented a process for rolling iron, that any considerable progress was made. John Payne was associated with Mr. John Hanbury, referred to by Mr. Coxe in his *Historical Tour in Monmouthshire*, published in 1801, as having invented in the early part of the eighteenth century a method of rolling iron plates by means of cylinders.

Originally, of course, iron only was employed for sheet-rolling. The number of heatings and rollings to produce a large sheet of soft steel was found to be much in excess of what was required to produce an iron sheet of similar size and gauge, as steel will not spread and elongate so readily as iron; consequently, much trouble was caused, in the early days of steel sheet-rolling, by the breaking of roller housings which were unable to withstand the heavier service imposed upon them under the changed conditions. Greater attention, too, was required during manufacture and in the subsequent annealing of steel than was required with iron. Further, for some time the quality of steel sheets was often unreliable through their being rolled from unsuitable material, the composition of which was frequently unsuitable for sheet-rolling. These difficulties have long since been overcome, and iron sheets are now almost a thing of the past.

The manufacture of sheets is not confined to any particular area, though it is more important adjacent to the ports—*i.e.*, in South Wales and Monmouthshire, the Liverpool area, the Clyde area, and a rapidly diminishing area in point of output in the Midlands. Sheets of ordinary size are rolled from sheet bars which are from 8 to 12 inches wide, and from $\frac{3}{8}$ to $\frac{7}{8}$ inch thick, the bars being ordered with a definite weight per linear foot, in order to facilitate the production of a sheet of a certain size from a given length of bar. Thus a sheet bar 0·525 by 8 inches is known as a 12-pound bar, because it weighs 12 pounds per running foot. Apart from home makers of sheet bars, for which South Wales is the principal producing district, large quantities of foreign bars are imported. The smaller makers are all buyers of their raw material, and even the largest firms purchase a large tonnage of foreign bars in normal times, as will be seen from the table on p. 120.

The bars before rolling are heated in a bar furnace. Material rolled to a thickness of less than $\frac{1}{4}$ inch is referred to by the trade as sheets, while above that thickness it enters the category of plates. Sheets of large size are rolled in small plate mills, but relatively small and thin sheets are produced in sheet mills, which are smaller and designed specially for the purpose. The rolls are chilled, the surfaces being accurately turned and given a high finish. The housings of these mills, which are usually made of cast steel, fit close up to the necks of the

* Contributed by Mr. Fokes, of the *Iron and Coal Trades Review*.

rolls, preventing their removal without first dismantling one of the housings; hence it is the usual practice to turn them in position, for which special provision is made. The earlier mills in Staffordshire employed rolls of from 18 to 20 inches diameter, rolling sheets of from 4 to 6 feet long by 2 feet 6 inches wide. Most sheet mills to-day have rolls 22 to 24 inches diameter, though 30-inch rolls are installed in some of the more recent mills in this country. Most of the sheet mills in this country are two-high, and are usually arranged in a line of three or four mills on either side of the prime mover, the rolls being driven either through gearing or ropes to give a roll-surface speed of from 200 to 220 feet per minute, or up to, say, 30 revolutions per minute. The bottom roll only is driven, the top one revolving by frictional contact with the material passing through the mill. The screw-down gear is operated by hand as the duty is not heavy. When the sheets being rolled are very thin, no draft is allowed between the rolls, which are screwed right down, the spring of the housing being sufficient to allow the sheet to pass. Present practice is to have two pieces passing through the rolls at one time.

IMPORTS OF SHEET AND TINPLATE BARS INTO THE UNITED KINGDOM, 1912, 1913, 1922, AND 1923 (TONS).

	1912.	1913.	1922.	1923.
Netherlands	—	—	?	6,014
Germany	240,286	267,519	?	1,194
Belgium	14,126	62,482	44,957	86,999
France	20,935	12,852	14,054	28,516
United States	—	2,650	135	250
Luxemburg	—	—	?	20,954
Other countries	—	—	11,055	85
Total (tons)	275,347	345,503	70,201	144,013
Value (£)	1,274,284	1,708,381	509,196	1,026,995

One man is stationed on each side of the mill, the one on the front side, adjacent to the furnace, called the roller, and the one on the other side called the catcher. Two pieces of bar are passed on to the foreplate, which is a flat plate on the entering side of the mill. The roller with his tongs pushes the top bar into the rolls so that the length of the bar is parallel to them, while the catcher receives it with his tongs as it comes through, and by a peculiar swing throws it up on top of the top roll. The roller pushes the second bar into the "bite" of the rolls, and then quickly catches the front end of the first rolled bar now coming over the top roll, and lets it drop on to the foreplate and presses it into the mill. This process of rolling and passing over takes place three or four times for each bar and it is done so quickly that one piece has hardly left the mill before the next one enters. The two pieces are then matched—*i.e.*, one laid on top of the other, and given one pass through the mill, generally in the finishing mill, but sometimes in the rougher. They are then placed in a pile on the floor on the catcher's side. In the case of sheets lighter than about 20 gauge, the matched sheets are doubled back on themselves before reheating, and the bend

flattened down in a doubling machine, making a pack four sheets thick. For still lighter gauges, instead of two sheets being laid together, there are three, making, when doubled over, a pack of six sheets thick. The sheets are then reheated and taken to the finishing stand, where the same rolling and passing over process takes place. On this stand there are rolled two, three, four, or six thicknesses at a time, depending on the gauge. A third heating is required for some gauges.

It has been usual in this country to finish sheets in one pair of rolls, but recent sheet mills put down here do the roughing in one pair of rolls and finish in a second pair. Pair furnaces which are operated at a considerably lower temperature than the bar furnaces are employed for reheating the roughed-out sheets for the second and third rollings. The sheets in the packs are separated by hand, though in some instances this is performed mechanically. To give the sheets a good surface and prevent their sticking together in the pack, the phosphorus content of the steel should not be less than 0·04 per cent. Owing to the lightness of the sheets rolled, the output of sheet mills on a tonnage basis is rather low, the older Staffordshire mills turning out from 4 to 5 tons a shift per pair of rolls; but more modern sheet mills can produce about 70 tons per stand per week, a good deal depending on the gauge being rolled. A 30-inch mill will roll about 12 tons of 16-gauge sheets in eight hours, with corresponding reductions in tonnage for lighter gauges. Sheets are usually annealed after rolling, and for special purposes close-annealed in order to remove all stresses, and to render the material ductile. When a special finish is desired they are also cold rolled, and sheets so treated are known in the trade as C.A. and C.R. Steel used for ordinary sheet-rolling is low in carbon. The composition of this soft steel produced by the acid open-hearth process varies between: carbon 0·12 to 0·20 per cent., silicon 0·04 to 0·08 per cent., sulphur and phosphorus 0·02 to 0·06 per cent., manganese 0·4 to 0·6 per cent. A steel which gave excellent results in rolling thin sheets analyzed: carbon 0·1 per cent., silicon nil, sulphur 0·048 per cent., phosphorus 0·037 per cent., and manganese 0·487 per cent. Steel sheets intended for special purposes such as the manufacture of pens, etc., are produced principally in Sheffield and Scotland, and are cold rolled in special mills, short lengths of strip about 6 inches wide being used for this purpose. The strip is carefully pickled and close annealed. The rolls are internally water-cooled, and the rolling process takes place in oil. The output of this class of sheets is relatively small, and is an entirely special trade very different from ordinary commercial sheets.

The old process of galvanizing sheets consisted in dipping them by hand into a zinc bath. The time during which they were allowed to remain in the bath depended on the judgment of the workmen, and consequently the thickness of coating varied considerably. There were other drawbacks to this method, but they have been largely overcome by the introduction of mechanical appliances which are automatic in their operation. Sheets intended for galvanizing are usually rolled light to gauge, allowance being made for the thickness of coating. In preparation for the process sheets are annealed and straightened, and afterwards placed in a pickling bath, which, if it consists of a solution of sulphuric

acid, is maintained at a temperature of about 90° F., where the sheets remain for about twenty minutes. They are then removed to cold-water tanks for twenty-four hours. If the pickle consists of a solution of hydrochloric acid, it is unnecessary to raise the temperature of the bath; neither do the sheets require washing before coating, but merely time to drain, when they can pass forward at once to the galvanizing tank. There is but little difference in the cost of employing either hydrochloric or sulphuric acid, but the former has the advantages of being quicker and less objectionable in use. The bath consists of ordinary commercial spelter, and is kept at a temperature of from about 440° to 453° C. by means of a coke fire which surrounds it. The temperature is carefully regulated, as excessive oxidation results if the bath exceeds the limits mentioned.

Ammonium chloride is employed as flux, a box being placed at either end of the galvanizing bath. The plates are treated one at a time, entering the flux box at the feeding end, passing down between rollers, through the bath, and the flux box at the other end. While the galvanized sheets are still hot from the bath, they are plunged into cold water to remove all traces of flux. The appearance of the sheets depends on the time allowed to elapse between their emerging from the galvanizing bath and entering the water. Those instantly cooled and cleansed receive an even surface, while a spangled effect results from increasing the interval before washing. A small addition of tin to the bath also increases the crystallized appearance of the sheets. In some recent plants the sheets are allowed to cool, thus dispensing with the water tank. Roofing sheets for convenience in handling are galvanized before being corrugated.

In order to impart a degree of rigidity to galvanized roof sheets they are crimped with corrugations usually of 3 inches pitch. This applies to sheets of about 16 gauge and thinner. A better quality of material than is usually employed is necessary in thicker sheets to withstand the corrugating process, so that for the heavier gauges larger corrugations of from 5 to 6 inches are usual. Sheets having eight corrugations are those in most general demand and are invariably stocked. These sheets in their width give a covering surface of 2 feet when laid and fixed. Galvanized corrugated sheets may be obtained without extra charge on quoted prices in lengths from 5 to 9 feet, also additional inches usually can be obtained without extra charge, though delivery may be delayed. Extras are charged for sheets under 4 feet long and for unusual lengths and gauges; also when sheets are required with serrated or scalloped tops and with other modifications of ordinary corrugations.

Sheets are employed for such a wide variety of purposes that makers have laid themselves out to supply many different sizes and gauges; usual lengths are from about 9 to 12 feet, though sheets can be supplied 15 or 20 feet in length, while widths up to 5 feet 6 inches and over are obtainable. The gauge depends on the purpose for which sheets are intended, but thicknesses cover the whole range of gauges, the greatest demand being for sheets from about 20 to 28 gauge. Prices of sheets of convenient lengths and widths are based upon the thickness. They are usually classed as "singles," "doubles," "trebles," or "lattens" and "extra lattens." "Singles" are the thickest gauge rolled down to, and include, 20 gauge and below. These sheets are rolled singly, as their name implies.

"Doubles"—*i.e.*, sheets that are rolled in packs of two—include gauges 21 to 24, while "trebles" are rolled to gauges including 25 to 27, three sheets being rolled together in one pack. The term "extra lattens" is applied to sheets of 28 and 29 gauge.

In England and Wales the price of 26 gauge black sheets usually is about 15 per cent. higher than for 24 gauge, while 28 gauge is about 10 per cent. dearer than 26. In Scotland there is a difference of roughly 10 per cent. between the prices of 24, 26, and 28 gauge. Extras are charged on list prices for sheets of unusual dimensions.

As regards galvanized sheets, these are sold in bundles each weighing 2 hundredweights, or in cases of 5 hundredweights. The method of packing varies with the gauge and the market for which they are intended. For the Indian market No. 24 gauge is usually exported, the sheets being in 2-hundredweight bundles. The same applies to the South African market. On the other hand, galvanized sheets for the Argentine usually are of 24 gauge, but are packed in 5-hundredweight cases, while for the Australasian market sheets of 26 gauge are required, being shipped in felt-lined skeleton cases of 10 hundredweights. Various gauges of sheets are shipped to China, and are packed in 5-hundredweight cases.

NUMBER OF GALVANIZED SHEETS PER TON.

		Corrugated Sheets.										*Flat Sheets.*	
Size B.G.	*Corrugation (Inches).*	*Number of Sheets per Ton, except Australasia (length in Feet).* 5	6	7	8	9	10	*Australasia (length in Feet).* 6	8	9	10	*All 6 Feet Long.* *(Width. Inches).*	*No. of Sheets.*
16	8/3	70	58	50	44	—	—	—	—	—	—	—	—
	10/3	59	49	42	37	—	—	—	—	—	—	—	—
18	8/3	86	72	62	54	48	43	—	—	—	—	—	—
	10/3	74	62	53	46	41	37	—	—	—	—	—	—
20	8/3	114	95	81	71	63	57	—	—	—	—	—	—
	10/3	95	79	68	59	53	47	—	—	—	—	—	—
22	8/3	139	116	99	87	77	69	—	—	—	—	—	—
	10/3	116	97	83	73	65	58	—	—	—	—	—	—
24	8/3	168	140	120	105	93	84	140	104	92	84	24	174
	10/3	140	117	100	88	78	70	—	—	—	—	30	142
												36	118
26	8/3	223	186	159	139	124	111	196	148	132	118	24	240
	10/3	186	155	133	116	103	93	161	120	107	96	30	195
												36	162
28	8/3	240	200	172	150	—	—	220	165	146	132	24	274
	10/3	200	167	143	125	—	—	180	135	—	—	30	225
												36	187

A large proportion of the trade in sheets, as with other products, is done through merchants, who form a useful intermediary between the manufacturer and consumer. Merchants usually carry stocks of sheets that are in general demand, and are able to execute orders for small lots which manufacturers as a rule are unwilling to entertain.

The applications of sheets are of almost endless variety. They find a field of usefulness all the way from an ordinary metal trouser button to the coverings of locomotives and steamship boilers. Sheets are employed for the manufacture of spades, shovels, tubes, tanks, conveyers, coal baskets, colliery tubs, oil and grease drums, smoke stacks, frying pans, and funnels. From sheets are made gasometers, gas meters, gutters, cornices, office furniture, ferrules, ranges, and roofing. Expanded metal for reinforcing concrete is cut from sheets. They are also employed for constructing vehicle and motor-car bodies, and for railway carriage work, while cubicles for an almost endless variety of purposes can be readily constructed of sheets.

EXPORTS OF SHEETS UNDER ONE-EIGHTH INCH THICK AND GALVANIZED SHEETS DURING TWENTY-ONE YEARS ENDED 1923 (TONS).

Year.	*Total Sheets under ⅛ Inch Thick.*	*To British Possessions.*	*Total Galvanized Sheets.*	*To British Possessions.*
1903	42,003	25,409	352,052	210,551
1904	43,476	27,364	385,448	232,810
1905	58,818	29,372	407,021	201,011
1906	74,140	37,239	443,131	217,881
1907	67,591	38,363	467,889	256,414
1908	61,098	31,520	390,124	213,418
1909	67,657	34,086	494,826	263,533
1910	73,602	40,156	597,117	333,029
1911	75,120	40,494	617,557	371,902
1912	74,325	36,841	658,650	400,304
1913	68,152	41,178	762,075	480,605
1914	50,311	29,888	566,984	409,427
1915	98,076	32,029	286,421	183,645
1916	160,137	20,954	117,069	70,636
1917	153,075	4,098	18,926	9,067
1918	115,397	4,940	8,835	4,295
1919	133,297	28,396	185,939	124,348
1920	138,462	54,159	410,784	231,359
1921	48,660	20,641	211,603	131,971
1922	169,257	47,820	513,110	323,913
1923	282,925	44,868	602,360	372,784

The bulk of the sheets sent abroad are galvanized, and are used for roofing and for the construction of buildings where cheapness and ease of assembly are essential. Some sheets are exported in the black state, being galvanized in the importing country.

Exports of black sheets under ⅛ inch thick and of galvanized sheets represent from 15 to 20 per cent. of our overseas trade in iron and steel. In both cases a good proportion of the total tonnage goes to destinations within the Empire. The figures for 1923 can be scarcely taken as representative, since shipments to Japan following the earthquake last year increased very rapidly, and resulted in the exports to that country being 175,573 tons compared with 56,371 tons in the previous year. In 1913 we sent Japan less

than 7,000 tons of black sheets. This is a convenient market for the United States, though since the War we have been able to secure more of this business than formerly. Our total export tonnage of black sheets twenty years ago was round 40,000 tons per annum; to-day, apart from special circumstances which may arise to cause a temporary demand, this trade should amount to something like 200,000 tons a year.

The markets for black sheets are as set out in the following table:

EXPORTS OF IRON AND STEEL SHEETS UNDER ONE-EIGHTH INCH THICK FROM THE UNITED KINGDOM IN 1913, 1920, AND 1923 (TONS).

Country of Destination.	1913.	1920.	1923.
India	13,187	38,895	15,621
South Africa	1,473	1,623	1,922
Australia	8,258	5,644	17,244
New Zealand	3,216	1,375	2,204
Canada	13,795	1,809	5,103
Other British Possessions	1,249	4,813	2,774
Total	41,178	54,159	44,868
Russia	1,761	2,172	—
Sweden	770	1,035	5,385
Norway	—	1,358	1,427
Denmark	553	2,572	1,049
Netherlands	—	2,352	2,163
Germany	325	88	9,926
Belgium	825	2,450	3,298
France	1,105	14,717	12,106
Switzerland	469	238	157
Portugal	—	2,564	1,160
Spain	405	2,683	1,391
Italy	2,938	5,239	767
China	908	4,886	5,549
Japan	6,863	30,855	175,573
United States of America	1,796	1,305	874
Chile	2,605	366	4,798
Brazil	—	2,140	1,888
Argentine	2,100	3,028	1,858
Other foreign countries	3,551	4,255	8,688
Total	26,974	84,303	238,057
Grand total (tons)	68,152	138,462	282,925
Value (£)	825,591	5,370,632	4,922,220

The Indian market for black sheets since the War has been again entered by Germany and Belgium, but the United States' share of this trade, which increased whilst the war was in progress, has now greatly diminished. Our own share has varied since the War. In 1920 our exports of black sheets to India amounted to 38,895 tons; they reached just over 30,000 tons in 1922, but

last year they only amounted to 15,621 tons. Exports of galvanized sheets in 1913, 1920, and 1923 are given in the table below:

EXPORTS OF GALVANIZED SHEETS FROM THE UNITED KINGDOM, 1913, 1920, AND 1923 (TONS).

Country of Destination.	1913.	1920.	1923.
India and Ceylon	244,937	76,741	154,033
Straits Settlements	8,317	6,097	9,666
South Africa	44,937	34,201	34,828
Canada	32,198	6,485	7,336
Australia	104,450	59,721	112,197
New Zealand	22,921	23,025	21,721
Other British Possessions	23,730	25,089	33,003
Total	480,605	231,359	372,784
Norway	4,226	2,767	5,299
Sweden	—	1,466	5,029
Denmark	4,261	1,068	6,638
Netherlands	2,761	1,579	2,556
Java	18,166	15,466	7,639
Siam	3,541	253	2,580
China	6,763	10,728	14,509
Japan	35,563	29,477	19,323
Portuguese East Africa	7,569	6,330	5,541
Chile	15,674	8,080	6,970
Brazil	19,538	6,543	8,571
Argentine	75,094	50,214	84,418
Other South America	11,801	8,512	10,219
Other foreign countries	76,513	36,942	50,284
Total	281,470	179,425	229,576
Grand total (tons)	762,075	410,784	602,360
Value (£)	10,026,317	19,112,272	12,567,395

In the period 1904-13 our exports of galvanized sheets nearly doubled. Shipments in 1923 amounted to 602,360 tons, but this was about 160,000 tons less than 1913—the highest record reached. Considerably more than half of the galvanized sheets exported from this country are sent to various parts of the British Empire, the principal foreign markets being the Argentine Republic. The total exports to the South and Central American markets last year amounted to 110,000 tons, of which the Argentine accounted for 84,400 tons. Of the British Empire, the Indian market for galvanized sheets stands first, with Australasia a good second. Exports to India and the adjacent markets in 1913 amounted to over 253,000 tons, compared with which last year's total of 163,700 tons shows a large reduction, though in spite of keen competition, especially from the Continent, we have increased our exports during the past three years, and there seems every possibility of again increasing the tonnage during the current year.

In 1913 exports of British galvanized sheets to Australia and New Zealand reached just over 127,000 tons, so that last year's total of 133,900 tons represents a substantial increase, especially in view of the fact that now Australia herself is a producer of this material. The African market—including the Gold Coast, etc.—for British galvanized sheets remains in about the same position as it occupied before the War. In 1913 we shipped 57,500 tons to these destinations.

CHAPTER XI

*STEEL WIRE AND ITS MANUFACTURE**

WIRE-MAKING is one of the most ancient of the metal-working crafts, and no doubt came into being when man first required a piece of drawn-out iron from which to make either weapons, tools, personal ornaments, hooks, or other form of fastening. It is more than likely that the first wire was made out of copper or gold, as both of these metals would be found in their native state, their plastic properties enabling the worker to beat out the metal in the easiest possible manner.

The first piece of iron rod or wire was, of course, forged directly from a lump of crude iron, then came the period when iron was beaten into thin plates, cut into strips, and rounded by hammering or rubbing.

Early metal workers do not seem to have been acquainted with the process of making wire by passing the metal through a draw-plate, for as long as the wire was formed by the hammer the artists of Nurnberg, by whom it was made, were styled wire-smiths, but with the introduction of the drawing process their designation was changed to wire-drawers or wire-millers. As far as can be determined this operation occurred as early as 1351 and 1360 in the histories of Augsberg and Nurnberg respectively; consequently it may be said that the invention of the wire-drawing plate dates from the fourteenth century. However, as the process is so simple, it is quite possible that much earlier metal workers used this means of reducing the diameter of a piece of wire or rod. All that we can say is that this method of wire-drawing was in operation at the dates mentioned.

The earliest wire made by the use of the draw-plate was no doubt manufactured by main force, the operator pulling the wire directly through the hole in the draw-plate. After this stage came the use of a form of hand machine, by which the workman was able to exercise considerable leverage in pulling the wire through the draw-plate. It was then an easy stage to the application of power, the first kind used being that of water. Although it is not clearly established, it is fairly certain that this type of machine was first constructed at Nurnberg by a person named Ludolf, who kept it secret for some time, and made a small fortune by the use of it. Nurnberg also gave birth to many subsequent improvements in the manufacture of various kinds of wire.

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Wire-drawing in Olden Times.

It is possible that iron wire was manufactured about the middle of the fifteenth century in England, as at that period the importation of wire into England was prohibited. In 1565 is recorded the granting of patents to certain Dutchmen or Germans for the prosecution in England of various manufactures, among which is that of wire. Prior to that time all English iron wire appears to have been drawn by manual strength in the Forest of Dean and elsewhere.

By the year 1630 the manufacture seems to have made such progress that in a proclamation of Charles I. it is alluded to as a manufacture of long standing, and one which employed many thousands of persons, and also that the quality of the product was much better than that which came from foreign parts. The first wire mill in England was set up at Sheen, near Richmond, by Dutchmen, in 1662. The wire-drawing business either followed cloth manufacture or was determined by the approximate location of coal and iron, for it soon took deep root in the neighbourhood of Barnsley in Yorkshire. Towards the end of the eighteenth century the trade commenced at Warrington, the largest manufacturers there, Rylands Bros., Ltd., holding the unique record of having made wire for 120 years. The employees of the firm now number about 2,000, the production being about 1,500 tons of finished wire and wire goods per week.

For the making of iron wire in the early days the best iron was selected, and before the introduction of the process of rolling with grooved rolls the bars were prepared for manufacture by being hammered into convenient rods of about the thickness of the little finger. They were then run down or reduced by a method of coarse drawing called "ripping" or "rumpling." After this process they were carried on through smaller and smaller dies until the required size of wire was obtained.

Modern Methods.

When the rolling of bars came into use, wrought iron for wire-drawing purposes was rolled down into rods of about $\frac{1}{4}$ inch in diameter, the weight of the piece usually being about 28 pounds. The introduction of mild steel or ingot iron has changed the character of the wire-drawing trade, for, as in other industries, mild steel has almost pushed the use of wrought iron out of existence. With the exception of a little Swedish charcoal iron, wrought iron has almost ceased to be used in the making of wire. Mild steel is usually purer and more uniform in its composition than ordinary wrought iron, and consequently much heavier pieces can now be drawn than obtained in the old days.

Whilst the raw product that comes into a wire works is the rolled rod from the steel mill, it is, perhaps, as well for us to look back a little at the earlier stages through which the steel has to pass before it comes to the wire mill. The steel, of course, originally comes from the iron ore which is smelted in the blast furnace. After smelting the hot metal passes to the steel furnace, and is there purified. In this process its impurities—such as phosphorus, silicon, sulphur, etc.—are very largely removed. After being stripped from the mould the ingot is reheated

or soaked, passed through the cogging mill, and ultimately rolled down into billets of about 2 inches square.

To produce the rods the billets are charged into a furnace and heated up to the required temperature, afterwards being passed through a continuous train of rolls and reduced down to about $\frac{1}{5}$ inch in diameter.

The Cleaning of Rods and Wire.

One of the most important processes in connection with the making of wire is the proper cleaning of rods, so as to free them entirely from any form of scale, as this latter is fatal to good wire-drawing. The general practice is to submerge the rods in cisterns of dilute hydrochloric acid until the whole of the scale has been completely " pickled " away. After cleaning in this form the rods are then washed well and allowed to stand until they are " browned," or coated with a film of ferric hydrate. This " coating " of wire is exceedingly important, and should be carried out with great care, as the subsequent drawing of the wire, especially for what is known as long-holing or carrying the wire to fine gauges, depends very largely upon the proper coating of the wire.

After coating, the rods are dipped into a vat of hot limewater, lifted out, and well dried in ovens. The thin coating of lime on the top of the ferric hydrate serves the double purpose of protecting the brown coat and also of keeping the rod surface from corroding.

Before either rods or wire can be passed through the drawplate it is necessary that the ends should be pointed to a conical form. This was originally done by hammering or filing, or a combination of both. The bulk of the pointing at the present time is done by the aid of either rotary swaging machines or grooved rollers; in some cases other special mechanical devices are used for forming the point.

Methods of Wire-Drawing.

There are two general processes of wire-drawing in vogue—one known as the " dry " and the other as the " wet " method. In dry drawing the rod or wire is passed through a drawplate or die which has a tapered hole, the lubricant in this case being a special form of well-dried soap. In wet drawing the wire or rod is first coated with a thin film of copper, the latter being deposited by passing the rod or wire through a special solution containing sulphate of copper. The wire then passes through a soapy solution and on through the hole of the drawplate. This method of wire-drawing a hard metal within a shell or skin of a softer metal has been in use for more than a century, and in practice gives very good results.

The rods as they come into the wire mill are usually in pieces weighing about 150 to 170 pounds, which will give a length of about a quarter of a mile of 5 gauge. This, when drawn to 10 gauge, increases in length to about three-quarters of a mile. If drawn to 20 gauge its length works out to about 9 miles, and then, if drawn further to 30 gauge, stretches to a length of 70 miles, or 280 times the length of the original rod. Sometimes rods of twice the above weight are used, these, of course, giving wire of double the length stated.

A continuous process of wire-drawing is now in common use. The method consists in carrying the wire continuously from one block to another through interposed drawplates, and thus on to a final winding block. The advantage of this method is that it obviates the handling of the wire in between the various passes or drafts.

Science of Wire-Drawing.

Whilst the casual observer would think that the making of wire is a very simple process, which involves little knowledge or skill, in actual practice to obtain the best results a great amount of consideration has to be bestowed on the kind of dies used, the shape of hole, speed of drawing, method of lubrication, and many other points that affect not only the drawing of the wire, but its ultimate quality.

Careful experiment and calculation show that the steel, in passing through the wire-drawers' plate, is subjected to an enormous pressure, this in some cases amounting to as much as 150 tons to the square inch. With such great pressure on the shoulder of the tapered hole in the drawplate, it is manifest that a solid or semi-solid lubricant must be used in wire-drawing. The commonest lubricant employed is the best hard, dry olive-oil soap.

It is essential in wire-drawing that there should never be metallic contact between the surface of the wire and the surface of the hole in the drawplate, as this causes the wire to scrape and wear out the hole in the plate, producing unsizeable wire. The arrangements for lubricating must be such that a film of the hard soap travels on the surface of the wire and keeps it from coming into contact with the surface of the hole in the plate.

The speed at which wire travels through a drawplate varies according to the diameter and quality of the material to be produced. For soft steel this speed may run up to 1,000 feet per minute. The reduction of area per draft varies according to the quality of steel being drawn and the kind of wire required. It may run up to 40 per cent. and down to 10 per cent.

The physical properties of steel are altered as it passes through the wire-drawing process, the chief alteration being a rapid increase in its tensile strength and a reduction in its elongation. A No. 5 gauge rod (0·212 inches) of 0·14 per cent. carbon steel, as it comes from the rolling mill, has a tensile strength of about 33 tons per square inch. In drawing down to 16½ gauge its tensile strength has risen to about 62 tons per square inch. This, again, after annealing, when drawn down to 33 gauge, mounts up to about 85 tons per square inch. The 0·75 per cent. carbon steel starts with a 5-gauge untempered rod, having a tensile strength of about 57 tons per square inch, but when drawn down to 33 gauge, with two intermediate temperings, it runs up to the extraordinary strength of 200 tons per square inch.

When stress-strain diagrams for mild steel wire are taken on an automatic recording machine the chief characteristic observed is the great reduction in the elongation as the wire is reduced in diameter. Similar curves for hard steel wire indicate that whilst the untempered rod shows a definite yield point, the tempered rod and the drawn wire give no clearly defined yield point.

The limit of elasticity for both mild steel and hard steel wire is not easy to

determine on account of the very slight deviation from the law of proportionality which obtains with wire under a small load.

The operation of wire-drawing on steel, it might be mentioned, has the effect of increasing its electrical resistance, so that in practice it is necessary to anneal wire that is to be used for telegraph and similar purposes.

The various physical properties that are usually mentioned in connection with wire are its tensile strength, elongation, limit of elasticity, torsion, and bending.

Torsion is usually defined as the number of twists in 100 diameters, or other definite length, which a wire will stand before fracturing, but there is no physical property which is so erratic and upon which so little reliance can be placed as that of twisting, as it seems to be very largely a measure of no other physical condition of the wire but its own, and this varies so considerably under all kinds of treatment of the steel that in itself it appears to be of very little use for practical purposes. However, it has become more or less a fetish with some engineers to specify for this particular property in the wire, but the time is certainly ripe for a thorough investigation into the torsional properties of steel wire to find out in which ways they can be correlated to something of practical use.

Under the Microscope.

The use of the microscope plays an important part in connection with wire-drawing, as it enables us to see what is happening as the steel passes through the plate, and also places the wire manufacturer in the position of being able to tell the quality of materials which give him the best results in wire-drawing, and to understand the cause of certain peculiar phenomena which sometimes occur in connection with the various processes.

It need not be explained in these days of advanced knowledge that mild steel is composed of a vast number of crystal grains which can be readily detected under the microscope. As the steel rod passes through the hole in the wire-drawers' plate these grains become crushed and elongated, in fine wire being drawn out to a great length.

The use of the microscope also enables the wire manufacturer to test the quality of tempering, and to have this so regulated as to produce the strongest and toughest wire which it is possible to make from any particular steel.

Uses of Wire.

A short time ago Sir Peter Rylands broadcasted a talk on this subject, and perhaps a quotation from his remarks will not be out of place:

" It is probable that few people realize how large a part is played by wire in our national and domestic life. If we look round a room we may find the pictures are hung by wire to nails made of wire, driven into the wall, which, in its turn, is sometimes constructed of plaster, built up on a wire foundation.

" The light from an electric bulb is caused by heating a thread of wire drawn from some refractory metal, such as tungsten, the current flowing to the lamp through a conducting wire made of copper. A wire also carries current to the

electric bell, and this may be fastened by a wire staple driven into the skirting board.

"The door hangs on hinges attached by wire screws, while a piece of square wire connects the door knobs, and wire plays an important part in the lock itself.

"The floor-boards are fastened down with wire nails, while grates and fenders are frequently built up with wire bolts.

"The chalet curtains run on wire rods, and the curtains are suspended by wire hooks.

"The periodicals and books lying on the table will be found to be stitched with fine tinned wire, and even the flower-bowl will frequently contain a wire mesh for supporting the flowers. Even the glass jingles in the old-fashioned crystal candelabra are hung with wire. The roller blinds are controlled by coiled wire springs, and the easy chairs and sofa derive their comfort from spiral springs worked in the upholstery.

"The lady's pins and needles are all made from wire, as are also her hooks and eyes, the old-fashioned crinoline, and the more modern wire hair-curler. Her artificial flowers are supported with wire, and hundreds of tons of wire a month are used in the soles of boots.

"In the larger sphere, except by wireless, all telegrams and telephone messages pass over a wire; our fields are fenced with wire and the depredations of rabbits are controlled by wire netting. The foundations of roads are frequently reinforced with wire, and all the coal we burn is raised from the pits with wire ropes. Indeed, the uses of wire are almost countless, and yet the wonder of wire production is little realized."

What the future may show in the use of wire it is difficult to say when one realizes that even at the present time wire is used for such diverse purposes as corset bones, suspension bridges, and the balancing of dolls' eyes. Every day seems to find some fresh use for wire, consequently its uses seem to be almost limitless.

Prior to the War a considerable tonnage of wire rods was imported into the United Kingdom. During and since the War the capacity for rolling wire rods has been very much increased, so that since the War imports of wire rods have been much reduced. Exports of wire, on the other hand, were 30 per cent. higher in 1923 than in 1913.

IMPORTS OF WIRE RODS INTO THE UNITED KINGDOM, 1913, 1922, AND 1923 (TONS).

Country of Consignment.	1913.	1922.	1923.
Sweden	12,123	3,602	4,389
Germany	60,263	2,755	6,994
Netherlands	—	9,083	2,668
Belgium	22,740	21,823	24,434
France	—	9,260	6,572
United States	53	153	371
Other countries	17	2,787	3,859
Total (tons)	95,196	49,463	49,287
Value (£)	648,156	518,987	483,093

EXPORTS OF WIRE AND WIRE MANUFACTURES FROM THE UNITED KINGDOM, 1913, 1922, AND 1923 (TONS).

Country of Destination.	Wire.			Wire Manufactures.		
	1913.	1922.	1923.	1913.	1922.	1923.
India and Ceylon	2,623	2,413	5,069	3,865	3,801	6,197
Straits Settlements ..	933	3,052	?	617	655	?
Hong Kong	—	—	?	248	466	?
Egypt	—	58	?	261	112	?
Canada	2,813	1,630	4,074	3,953	2,243	3,883
South Africa	6,916	3,260	6,520	6,862	5,126	9,007
Australia	7,270	17,441	19,492	13,952	7,999	12,090
New Zealand	8,010	6,989	8,857	3,947	2,656	4,131
Other British Possessions	1,415	1,298	?	3,320	1,690	?
Total	29,980	36,141	?	37,025	24,748	?
Russia	2,774	1,149	?	346	397	?
Sweden	—	39	?	199	205	?
Norway	247	326	?	981	726	?
Denmark .. .	—	171	?	291	303	?
Germany	1,456	78	662	918	1	267
Netherlands	784	690	?	1,528	1,062	?
Belgium	1,830	1,024	?	1,256	364	?
France	1,660	1,119	?	638	343	?
Portugal	135	1,176	?	481	231	?
Spain	314	456	?	1,313	803	?
Italy	547	168	?	220	29	?
China	—	368	?	275	721	?
Japan	655	1,294	?	1,183	197	?
Mexico	—	—	?	218	90	?
Cuba	—	—	?	?	7	?
Chile	449	1,111	?	879	358	?
Brazil	1,322	1,385	2,752	498	402	416
Argentine	5,530	1,791	4,810	1,520	439	680
United States	5,562	2,933	2,507	1,281	232	371
Other foreign countries ..	7,287	3,081	?	4,689	3,019	?
Total	30,552	18,359	?	18,714	9,929	?
Grand total (tons) ..	60,532	54,500	78,596*	55,739	34,677	52,572†
Value (£)	1,058,075	1,428,402	2,169,984	1,453,487	1,746,650	2,469,179

* Includes 23,853 tons for which no details are yet available.
† Includes 15,530 tons for which no details are yet available.

CHAPTER XII

*SHIPBUILDING MATERIAL**

SHIPBUILDING consumes more iron and steel than any other single industry. A Departmental Committee which reported in 1917 as to what would be the position of the shipping and shipbuilding industries after the War went carefully into the question of the quantity of iron and steel consumed by British shipbuilders and marine engineers, and came to the conclusion that in 1913 the total quantity of steel materials incorporated in war and merchant ships and marine engines constructed in 1913 was not less than 1,400,000 tons; they estimated that the weight of ingots to produce this steel would be not less than 1,850,000 tons. The total quantity of steel ingots produced in the United Kingdom in 1913 was 7,763,000 tons, and, allowing for imports and exports, the amount of steel consumed was about 6,325,000 tons, so that the shipbuilding and marine engineering industries accounted for fully 29 per cent. of the total consumption. The Committee collected information from all shipbuilding and marine engineering firms in the United Kingdom (except Admiralty dockyards), and stated that the quantities of steel plates and sections delivered to these firms in 1912 and 1913 respectively amounted to 952,000 and 896,000 tons. The Board of Trade returns do not distinguish between plates and sections for shipbuilding and marine engineering purposes, and those for other purposes, but from an examination of such figures as were available the Committee estimated that the total quantity of imported plates and sections for shipbuilding purposes was certainly below 10 per cent. of the aggregate quantity used. The quantity of forgings and castings delivered by British makers to shipbuilding and marine engineering firms in the United Kingdom is set out in the figures on p. 135.

While the rate of shipbuilding may be taken in a general way as an index of the prosperity or otherwise of the country, the iron and steel trade is particularly sensitive to fluctuations in the shipbuilding industry, and this applies especially to the steel works in Scotland and on the North-East Coast, which supply so large a proportion of the shipbuilding material of the country.

The figures given on p. 135 show the shipbuilding tonnage under construction, and launched quarter by quarter from 1920 onwards, and go a long way to account for the lower production of steel in 1921, 1922, and 1923, especially on the North-East Coast and in Scotland.

Neither the production statistics nor the foreign trade statistics differentiate between ships' plates and other plates over $\frac{1}{8}$ inch in thickness, and it is therefore necessary to give the total figures for plates. The effect of the shipbuilding depression is, however, obvious.

* The editor desires to acknowledge, with many thanks, valuable help received from Mr. G. P. West, of Messrs. David Colville and Sons, Ltd., in compiling this chapter.

TONNAGE OF FORGINGS AND CASTINGS DELIVERED BY BRITISH MAKERS TO SHIPBUILDING AND MARINE ENGINEERING FIRMS IN THE UNITED KINGDOM, SHOWING THE PROPORTION THIS BORE TO THE TOTAL AND THE PERCENTAGE IMPORTED FROM FOREIGN COUNTRIES IN 1912 AND 1913 (INCLUDES ADMIRALTY WORKS).

	1912 (*Tons*).	1913 (*Tons*).	*Percentage British.* 1912.	*Percentage British.* 1913.	*Percentage imported from Germany.* 1912.	*Percentage imported from Germany.* 1913.
Forgings of steel:						
Stems, stern-frames, rudders and parts thereof, also propeller brackets	2,098	2,196	95·0	95·5	5·0	4·5
Shafts—crank, thrust, intermediate, and propeller	18,430	18,978	56·4	57·3	35·9*	35·4*
Other forgings for marine engines ..	7,472	6,037	89·4	85·7	9·4*	12·2*
Forgings of iron:						
Stems, stern-frames, rudders and parts thereof, also propeller brackets	5,837	5,346	99·2	99·8	0·4†	—†
Shafts—crank, thrust, intermediate, and propeller	1,551	1,436	98·7	97·0	1·3	3·0
Other forgings for marine engines ..	1,999	1,665	100·0	100·0	—	—
Castings of steel:						
Stems, stern-frames, rudders and parts thereof, also propeller brackets	2,770	2,928	78·5	77·4	19·1†	17·6†
Castings for marine engines ..	3,221	3,370	94·8	99·1	5·1†	0·8

TONNAGE UNDER CONSTRUCTION, COMMENCED AND LAUNCHED IN EACH QUARTER, 1920 TO 1923.

	Quarter Ending—	*Tonnage of Vessels under Construction.* Total.	*Tonnage of Vessels under Construction.* On which Work has been Suspended.	*Tonnage Commenced.*	*Tonnage Launched.*
1920	March 31	3,394,425	—	708,031	454,294
	June 30	3,578,153	—	588,604	522,943
	September 30	3,731,098	—	593,821	483,057
	December 31	3,708,916	—	506,353	579,933
1921	March 31	3,798,593	497,000	392,877	433,607
	June 30	3,530,047	735,000	69,028	321,690
	September 30	3,282,972	731,000	51,343	307,850
	December 31	2,640,319	722,000	55,290	467,246
1922	March 31	2,235,998	617,000	51,008	334,352
	June 30	1,919,504	481,000	38,877	148,886
	September 30	1,617,045	419,000	82,428	307,232
	December 31	1,468,599	348,000	231,187	260,588
1923	March 31	1,492,138	181,000	355,203	228,371
	June 30	1,337,759	130,000	241,283	239,373
	September 30	1,271,195	242,000	111,860	66,474
	December 31	1,395,181	164,000	244,506	114,583

* Remainder imported from Denmark.

† Remainder imported from Austria-Hungary.

Production of Steel Ingots and Plates in the United Kingdom, the North-East Coast, and Scotland, 1920–1923 (Tons).

	Total Output of		North-East Coast. Output of		Scotland. Output of	
	Ingots.	*Plates.*	*Ingots.*	*Plates.*	*Ingots.*	*Plates.*
1920	8,860,200	1,428,800	1,918,800	539,300	2,029,300	614,500
1921	3,600,100	599,700	988,600	267,000	566,400	215,900
1922	5,794,500	506,900	909,900	196,700	755,500	162,600
1923	8,334,500	922,500	1,657,400	415,500	1,236,700	313,200

According to the *Chronology of Iron and Steel* compiled by Professor S. L. Goodale of the University of Pittsburg, the first iron vessel of importance made its appearance on the canal at Birmingham in 1787. It was 70 feet in length, 6 feet $8\frac{1}{2}$ inches beam, and built of $1\frac{5}{16}$ inch iron plates. In this year also John Wilkinson used iron barges to transport castings down the Severn from his Coalbrookdale works. The first iron vessel in Scotland was a barge named *Vulcan*, built on the Monkland Canal in 1818, which remained in service until 1875. According to the authority just quoted, the first iron ship that ever went to sea was the *Aaron Manby*, built by the Horseley Company near Birmingham, and put together in London. She made her first passage between London and Paris in the year 1820. In 1858 Laird and Company of Greenock built the first ocean steamship. The introduction of iron for the construction of warships took place in 1860-61, when H.M.S. *Black Prince* and *Warrior* were laid down, and iron still continued to be largely used until the introduction of steel for warships in the early eighties. The first vessels in which the British Admiralty used steel as an exclusive main material were the *Iris* and *Mercury* in 1876. In 1877 steel was introduced generally for the construction of ships, and in 1878 eleven steel vessels were built.

In 1913, as we have seen, the shipbuilding industry consumed 1,400,000 tons of steel; during the War the submarine campaign forced us to increase our shipbuilding capacity to a very considerable extent, which in turn demanded an increase in the capacity for producing shipbuilding material. As a result, the country has to-day a capacity for producing shipbuilding material somewhat approaching 3,000,000 tons, in addition to meeting the demand for ordinary structural purposes. In addition to the steel works throughout Britain supplying the wants of the shipbuilding establishments in our own country, a relatively large quantity of steel is also produced for export for shipbuilding purposes, and among the ports which are supplied from this country might be mentioned those in Norway, Sweden, Finland, Danzig, Holland, Spain, Burmah, Siam, Straits Settlements, Japan, Canada, United States, India, Australia, Belgium, France, and Italy.

The following table shows the distribution of the exports of plates in 1912, 1913, 1922, and 1923, though it must be remembered that all the plates are not ship-plates. A great deal of the material exported to India, for instance, would be for pipe-line and irrigation purposes.

EXPORTS OF STEEL PLATES FROM THE UNITED KINGDOM, 1912, 1913, 1922, AND 1923 (TONS).

Country of Destination.	1912.	1913.	1922.	1923.
India and Ceylon	17,239	32,293	18,488	52,285
Egypt	1,588	797	471	1,332
Straits Settlements	3,191	3,227	1,169	3,701
Hong Kong	3,854	5,646	4,377	5,809
South Africa	6,514	4,963	2,951	7,339
Canada	2,801	5,744	1,178	9,846
Australia	15,636	19,504	10,981	31,722
New Zealand	4,708	4,727	3,705	3,942
Other British Possessions	3,330	5,522	2,241	2,335
Total	58,861	82,423	45,561	118,311
Sweden	5,811	916	912	3,057
Norway	6,889	2,938	1,144	3,050
Denmark	12,486	3,076	1,156	9,222
Germany	2,783	339	—	23,073
Netherlands	2,528	1,099	1,976	6,865
France	3,124	1,067	944	1,049
Spain	1,874	2,136	1,442	3,991
Italy	1,750	980	2,444	318
China	3,814	6,152	2,796	2,830
Japan	27,322	18,763	12,884	8,519
Chile	2,723	3,574	459	1,486
Brazil	1,743	2,370	507	1,004
Argentine	1,815	2,376	1,299	1,703
United States of America	316	485	—	227
Other foreign countries	7,105	5,255	8,236	7,743
Total	82,083	51,526	36,199	74,137
Grand total (tons)	140,944	133,949	81,760	192,448
Value (£)	1,192,396	1,232,998	1,878,164	2,176,029

As we have seen, a certain portion of the material used in the construction of ships is imported. Aided by the depreciated exchange and low standard of living at the moment of writing, German competition is reappearing on the Clyde. In this connection it is interesting to note that the report of the Committee on shipbuilding, while not recommending the imposition of a duty on materials for shipbuilding and marine engineering imported into the United Kingdom, did suggest that an attempt should be made to stop "dumping" by means of legislation on lines similar to provisions already in force in the United States and Canada.

Although iron has been so largely replaced by steel in the construction of ships, cables, which, of course, form a very important part of the ships' equipment, are still made of iron, the special virtues attaching to this material being considered by those responsible to be the more suitable for the services they are called upon to perform.

It may, however, be mentioned that experiments and preliminary trials have

been made in the production of cast steel cables, and there is at least a probability that eventually the results will lead to serious consideration of this class of material for the purpose in question.

Steel castings are in general use for such parts of the ships as stems, stern posts, rudder frames, and other portions where intricate form and other circumstances render such castings suitable for the different purposes, but the structural steel is, in general, rolled material, bent, forged, and/or otherwise worked to meet the requirements of the ship.

In the early days of steel shipbuilding Bessemer steel was used, but except for a comparatively small proportion of the castings which are made by the converter process, the electric furnace, or the crucible, the whole of the steel for shipbuilding is now manufactured entirely from open-hearth Siemens furnaces, some with acid and others with basic linings, it being generally permissible to use either the acid or basic process provided the requirements of the specifications are met. The capacities of the furnaces in different districts and at different works vary somewhat considerably in order to meet different circumstances regarding the production, but in general the capacities vary from 25 tons to 100 tons per "tap."

In some districts the hot metal process is operated, and by this method it is the practice to take the iron from the blast furnaces in the molten condition and turn it into the mixers and thence into the steel furnaces, whilst in other instances where it is not practicable to use this method, entirely cold material—*i.e.*, pig iron, etc.—is put into the smelting furnaces direct. In either case the product from the smelting furnace, after having reached the desired quality and condition, is tapped into moulds, the ingots being then dealt with by being passed through the cogging mill, thence to the sectional or plate rolling mill as the case may be, and subsequently being trimmed or cut to shape as required by specification.

At all steel works there are fully equipped laboratories where trained chemists and metallurgists analyze and examine all raw materials to be used, and test the steel in process and on completion of manufacture with a view to ensuring that it will meet specified requirements. There are fully equipped testing departments at each works, where the mechanical testing is carried through in the presence of the receiving bodies' surveyors before the material is accepted as satisfactory. These appliances consist ordinarily of planing, milling, and slotting machines for the purpose of preparing the samples of suitable size and shape for testing, furnaces for heating samples as required to specified temperature, quenching baths, and bending machines for bending the samples to the form required for satisfactorily meeting the requirements specified, and tensile testing machines. These latter are of various types and capacities from, say, 5 to 100 tons total pull, but the general principle is similar in most of them. The samples for testing are carefully prepared and measured for section and distance between gauge points before testing. They are then gripped in the testing machine, and the load for tension gradually applied until the sample breaks, after which the reading on the machine is taken, giving the actual tonnage on the piece at fracture, and the broken samples are then measured between the gauge points

resulting from which the tensile stress per square inch and elongation are readily arrived at.

In order to ensure that a uniformly satisfactory material shall be supplied for the various purposes intended, rigid rules are laid down by the classification societies, who have surveyors in constant attendance at the different manufacturing works watching the various processes of manufacture, and testing and examining the material before it leaves the steel works for the shipyard, following which the classification societies have surveyors also in constant attendance at each shipyard and engine works closely watching the different operations whilst the material is in process of being worked up.

The major portion of the steel manufactured in this country for shipbuilding purposes is dealt with under Lloyd's Register of Shipping; the other classification societies include Bureau Veritas, British Corporation, Germanischer Lloyds, and Norske Veritas. In addition to the foregoing, the Board of Trade also have surveyors dealing with boiler material, and they, too, insist on certain definite requirements being met, as also do the British Admiralty for material supplied for warships.

The specifications issued by the different societies and supervising bodies referred to above vary, of course, according to their requirements, but in general it may be taken that steel for shipbuilding is required to stand a tensile strength of 26 to 32 tons per square inch with elongation of 20 to 25 per cent. according to circumstances and the purposes for which the material is to be used. Samples for tensile testing are selected at the steel works by the surveyors of the inspecting bodies, and, based on the results obtained, the material represented is either accepted or rejected. This procedure also applies to tests taken from the plates, sections, etc., for ductility tests, bending samples being selected by the surveyors as cut from the flat plate or bar, and they are then bent in the steel companies' test houses to the required angle or curve to meet the requirements of the specification. Should these test samples fail, the material represented is rejected as unsatisfactory.

It will be seen, therefore, that with the elaborate methods employed there is but remote possibility of anything but satisfactory material eventually being worked into the ship or boiler as the case may be, and the system, too, ensures that manufacturers in producing the steel carefully watch, throughout the different processes, that they obtain results which will ultimately ensure satisfactory material in the finished plate or section.

For shipbuilding purposes material is rolled in varying thicknesses, in general from $\frac{1}{8}$ to 2 inches thick, and up to, say, 13 feet 6 inches diameter or width by 75 feet long. In special cases these dimensions can be exceeded by making special provision and arrangements in the mills. It may be necessary in some instances to have plates 3 to 4 inches thick, and in such cases certain steel-makers can fully meet what is required.

In respect to sections, these are of varying types—*i.e.*, equal and unequal-sided angles, obtuse angles, bulb angles, channels, H bars or joists, T bars, Z bars, bulb tees, round, square, and flat bars, cope and convex bars, and for other special sections which may be required by builders, if makers have

not the plant for dealing with the same, rolls are specially cut to meet requirements.

The rate of output of shipbuilding steel varies, of course, according to the plant employed and the description of material asked for. Some rolling mills for the lighter sections and sheets have an output of, say, 15 to 20 tons per eight-hours shift, whilst others, which deal with the heavier classes of material, have an output of up to, say, 300 tons per eight-hours shift.

In the case of sections, they are, in general, taken from the rolling mill and cut hot to required lengths by means of saws, whereas the plates and sheets are cut to dimensions after having left the rolls, and allowed to become cold. It may be mentioned, too, that for use for forging purposes steel-makers supply shipbuilders and engineers with steel blooms or slabs rolled from ingots and which, after re-heating at receivers' works, are forged or cut down as required. These blooms can be supplied up to a maximum length of about 50 feet, maximum width 70 inches, maximum thickness about 4 feet, and up to a weight regulated by the handling capacity at the different works, but in some instances up to 40 tons. Indeed, in some few cases heavier weights than these can be dealt with.

Ordinarily, steel of the mechanical properties before mentioned is specified for shipbuilding, and the known suitability of such material for the purposes required is based on careful experiments which have been made, and the results of usage by builders, for it is necessary to ensure that not only is there strength and rigidity in the material supplied, but its corresponding ductility must also be assured. It is, however, sometimes found, as in the case of warship material, that specially high tensile material with extreme ductility must be used for certain of the parts, and such material has been largely supplied by the steel trade. This material is sometimes asked for up to 38 tons per square inch tensile strength, with ductility practically the same as mild steel, and with a high elastic limit. Other special quality steels are supplied as required, but these come outside the category of ordinary supplies for shipbuilding purposes.

CHAPTER XIII

STRUCTURAL STEEL

Many volumes have been devoted to the subject of structural steel, while even the catalogues issued by the bigger manufacturers and merchants, giving the sizes of the various sections rolled, their weights, properties, etc., run to hundreds of pages. It is therefore extremely difficult to say anything in the brief space allotted to this chapter which will be useful to the purchasers of iron and steel. The catalogues just referred to give all the assistance possible to purchasers by means of illustrations, calculations, etc., so that the intending buyer will always do well to communicate his requirements direct to the manufacturer or through a reputable merchant, and he may be sure of expert attention, as both the

production and utilization of iron and steel have been reduced to an exact science.

As we have already seen in previous chapters, first iron and then steel gradually took the place of timber and other material for many purposes; so in all kinds of structural work steel has become the skeleton of modern structures. The first cast-iron bridge in Europe was that across the Severn at Coalbrookdale, which was designed and constructed by Abraham Darby between 1776 and 1779. Until 1877 the regulations of the Board of Trade did not permit the use of steel in the construction of bridges, and in 1859 Sir John Hawkshaw had been refused permission to use steel in the construction of Charing Cross bridge. In 1877, however, on the recommendations of a Committee, of which Hawkshaw was a member, the veto on the use of steel was withdrawn. The first bridge to be built entirely of steel was the Glasgow bridge over the Missouri, which was completed in 1879. In the middle "eighties" iron and steel were first used in the construction of offices and other buildings, especially at Chicago. Great Britain was later in introducing this method of construction, but one has only to walk down Regent Street to see what a vogue this type of building has at the present day. Not only does the steel "skeleton" ensure strength, but it also lends itself to the attainment of architectural beauty, and this has led to its adoption in the building of many public and business premises in all the chief cities of the Empire. That steel frame buildings are of considerable strength was clearly shown by their behaviour during the earthquake at San Francisco in 1906, and at Tokio last year, while they clearly offer great advantages as far as the risk of fire is concerned. The great advantages claimed for structural steel for building purposes are greater permanence and strength, speedy construction, economy of space, the fact that the steel frame serves as its own crane platform, thus obviating the necessity for unsightly scaffold poles, which impede the traffic, etc. Internal economy of space is achieved because main walls and partitions, not being subjected to structural loads, can be reduced to a minimum, and buildings can be carried to much greater heights as the loads transmitted to the foundations are much less than is the case in buildings with structural walls of reinforced concrete. The degree of standardization of rolled steel joists, channels, etc., which has been achieved by the British Engineering Standards Association has had a substantial effect in cheapening the price of British rolled steel, and enabled it more effectively to compete with the structural materials of the U.S.A. and the Continent. But while the sections have been standardized, design has not been standardized by engineers to any great extent, so that every type of structure is considered from the point of view of the ultimate uses it must serve. In the case of some of the leading firms in the country, the responsibility for the complete framing will be undertaken—the actual steel manufactured, the joists, channels, plates, angles, etc., rolled, the stanchions, girders, compound beams, etc., fabricated, and the structure erected under the control of one organization.

The structural shapes used in the building of bridges, ships, cars, buildings of all kinds, etc., are fashioned in the rolling mill, which was first introduced by Henry Cort in 1783. Great Britain rolled the first rails, angles, tees, and zeds; Germany the first plates; France the first I beams and channels; and the U.S.A.

the first segmental shapes. Joists were rolled both in Belgium and Germany earlier than in this country. The heavier sections are rolled direct from the ingot, but the lighter go first through the cogging mill and are reduced to billets, blooms, or slabs, and then finished in the " finishing " mill, which differs to some extent, according to the particular product rolled.

Each shape requires its own set of rolls, and adjustments are made in the finishing rolls for each different weight or thickness of the shape in question. The principal sections, which in most cases are fairly described by their name, are known as angles (which may be right, obtuse, or acute, and have equal or unequal sides), joists, beams, tees, zeds, channels, rounds, squares, flats, ovals, hexagons, convex bars, etc.

To take angles as an example, the section book of any well-known manufacturer will contain information as to the sizes and thicknesses of the angles rolled, the area in square inches, the weight in pounds per foot, the dimension or centre of gravity distance, moment of inertia, section modulus, radii of gyration, etc., which he rolls. In the case of unequal angles the angle of the minor axis to the longer arm would be added. A merchant doing a big business will be able to bring together the catalogues of many different makers, and give a more comprehensive list of the sections which it is possible to obtain. In the case of at least one well-known merchant, indications are given as to whether the sections are rolled by many makers or few, and consequently the ease or difficulty of quickly obtaining the desired section. Many merchants also act as stockholders, and can supply sizes in frequent demand from stock.

Similar information would be given with regard to bulb angles, channels, tees, and I beams. The catalogues both of manufacturer and merchant also contain useful information for the engineer as to the carrying capacity of beams, compound girders, stanchions, struts, etc., mathematical properties of various sections; " safe loads " for joists, angles, channels, etc.; load transmission, etc. Code words for facilitating ordering are also given.

Although structural sections have been standardized, a great many non-standardized sizes are available, but as a general rule, quicker delivery will be forthcoming for the standardized sizes. It does sometimes happen, however, that a section in frequent demand, for some reason or other, has not been standardized, or, on the other hand, that a standard size is only rolled by a few makers.

To conform to the British Engineering Standards Association specifications sectional material is required to give the following results: 28 to 33 tons tensile stress per square inch; 20 per cent. elongation in 8 inches.

The trade margin allowed in rolling sectional material is $2\frac{1}{2}$ per cent. above or below the dimensions and weights listed. All sections are cut to a margin of 1 inch over or under specified lengths, so that an order for a length of 12 feet might be met by material varying from 11 feet 11 inches to 12 feet 1 inch, and would cause inconvenience if an exact length was essential, and the buyer did not know of this rule. For cutting to within $\frac{1}{8}$ inch of exact length and for machining square an " extra " is charged. Except that joists are cold straightened before despatch without extra charge, rolled products are despatched with " usual mill finish," and it is usual to charge over and above the " basis " price for straightening,

oiling, bundling, etc., although all makers do not charge the same extras. Extras are also naturally charged for rolling special sizes and thicknesses.

Neither the production statistics nor the Board of Trade foreign trade statistics separate completely the production of the different kinds of structural material rolled. The production figures are given in three groups—viz., angles, channels, and tees; girders, joists, and beams; and rounds, squares, flats, and hexagons. The production in these three groups, which includes material for shipbuilding, rolling stock, etc., as well as for other structural purposes, over the last few years has been as follows:

	Sections, Angles, Channels, and Tees.	*Girders, Joists, and Beams.*	*Rounds, Squares, Flats, and Hexagons.*
	Tons.	*Tons.*	*Tons.*
1919	773,500	251,200	732,500
1920	872,800	389,900	866,900
1921	245,600	132,600	337,500
1922	370,300	215,000	541,900
1923*	618,400	319,300	745,300

The following table shows the principal districts producing structural material. Much of the output of the North-East Coast and Scotland would be utilized in shipbuilding, while much of the output of the Midlands would go in locomotive and rolling stock.

	Districts.						
	4. *North-East Coast.*	5. *Scotland.*	6. *Staffs, Shrops, Worcester, and Warwick.*	7. *South Wales and Monmouth.*	8. *Sheffield.*	*Remainder of United Kingdom.*	*Total.*
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Sections, angles, channels, etc.	196,500	165,700	131,600	21,800	9,200	93,600	618,400
Rolled girders, joists, and beams, etc. ..	181,100	32,500	23,800	9,500	200	72,200	319,300
Rounds, squares, flats, and hexagons ..	64,500	92,200	203,400	51,600	162,100	171,500	745,300

In the report of the Committee which considered what would be the position of the iron and steel trades after the War, which was issued in June, 1917, it was stated that the manufacturers associated in the British Joist Makers' Association "made 282,000 tons of joists in 1913, of which 189,000 tons went into the home market, and 93,000 tons were exported mainly to other parts of the Empire.

* Provisional figures.

In 1913 the proportion of the total make of ingot steel rolled into joists was 3·7 in Great Britain, 7·1 in Belgium, and 8·2 in Germany. Germany exported 87,800 tons of joists to the United Kingdom, and 49,500 tons to other parts of the Empire. British imports and exports of plain joists were approximately equal. German and Belgian joists were usually supplied without brand, and were capable of being passed off as British."

The following table shows the imports and exports of iron bars, rods, angles, and sections; steel bars, angles, shapes, etc.; and girders, beams, joists, and pillars according to the customs returns for 1912, 1913, 1922, and 1923. It will be seen that more iron bars are imported than are exported, and from the subsequent table it will be seen that these are mostly of the cheaper quality from Belgium. The export trade in steel bars, angles, shapes, etc., was higher in 1923 than before the War.

	1912 (*Tons*).	1913 (*Tons*).	1922 (*Tons*).	1923 (*Tons*).
Imports of:				
Iron bars, angles, rods, and sections ..	164,378	199,975	75,064	142,924
Steel bars, angles, shapes, etc. ..	108,889	135,592	36,491	84,249
Girders, beams, joists, and pillars .	116,726	109,000	39,006	61,438
Exports of:				
Iron bars, angles, rods, and sections ..	142,474	141,452	31,403	43,451
Steel bars, angles, shapes, etc.	241,051	251,059	214,451	337,130
Girders, beams, joists, and pillars ..	120,832	121,870	58,737	76,793

The countries from which we imported structural material in 1913 and 1923 were as follows:

	1913.			1923.		
	Iron Bars, Sections, Angles, etc.	*Steel Bars, Sections, Angles, etc.*	*Girders, Beams, Joists, and Pillars.*	*Iron Bars, Sections. Angles, etc.*	*Steel Bars, Sections, Angles, etc.*	*Girders, Beams, Joists, and Pillars.*
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Sweden	52,188	2,516	—	9,999	1,580	—
Netherlands .	—	1,060	24	2,588	1,529	279
Belgium	98,104	87,404	35,616	120,898	44,603	38,209
France	226	—	4,724	1,671	3,728	9,855
Germany	47,680	31,384	68,636	4,832	12,422	165
Luxemburg ..	—	—	—	2,520	3,030	12,800
United States of America	519	10,949	—	—	15,746	—
Other countries ..	1,258	279	—	416	1,611	130
Total	199,975	133,592	109,000	142,924	84,249	61,438

The following table shows the countries to which iron and steel bars, rods, angles and sections, and girders, beams, joists and pillars were exported in 1913 and 1923:

	1913.			1923.		
	Iron Bars, Sections, Angles, etc.	*Steel Bars, Sections, Angles, etc.*	*Girders, Beams, Joists, and Pillars.*	*Iron Bars, Sections, Angles, etc.*	*Steel Bars, Sections, Angles, etc.*	*Girders, Beams, Joists, and Pillars.*
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
India and Ceylon ..	14,918	46,433	46,963	4,109	48,131	22,964
Straits Settlements	2,907	5,195	6,446	347	6,436	1,186
Hong Kong ..	1,194	3,719	652	377	5,021	1,709
Egypt	344	2,060	1,366	231	4,100	1,949
British West Africa	1,837	921	1,376	886	1,803	394
South Africa ..	15,567	12,893	8,065	3,842	11,299	3,278
Canada	9,331	29,750	—	2,655	16,322	1,309
Australia	40,515	37,972	26,778	8,450	83,421	26,215
New Zealand ..	16,493	7,254	4,185	8,385	17,788	4,041
Other British Possessions ..	3,602	2,023	3,892	6,192	6,519	4,885
Total	106,708	148,220	99,723	35,474	200,840	67,930
Finland	—	—	—	14	3,820	12
Poland	—	—	—	—	1,057	—
Norway	316	6,573	—	140	4,380	17
Sweden	—	1,510	30	31	3,136	16
Denmark	275	4,197	—	167	7,354	118
Germany	—	5,301	—	309	26,207	196
Netherlands ..	971	4,823	128	324	9,512	77
Belgium	240	5,013	52	78	3,858	71
France	367	5,253	92	50	6,367	26
Portugal	468	893	25	231	2,416	142
Spain	991	3,093	537	133	6,657	395
Portuguese East Africa	1,661	1,876	792	457	4,292	234
China	1,636	6,490	968	289	8,097	366
Japan	2,273	20,653	2,664	1,227	20,700	5,331
Chile	2,360	1,525	1,569	700	1,945	526
Brazil	8,348	3,949	2,829	1,386	3,432	31
Argentine	6,942	5,491	7,790	556	4,990	190
United States ..	2,223	12,487	27	130	4,416	80
Other foreign countries ..	5,673	13,712	4,644	1,755	13,654	1,035
Total	34,744	102,839	22,147	7,977	136,290	8,863
Grand total (tons)	141,452	251,059	121,870	43,451	337,130	76,793

CHAPTER XIV

*HOOPS AND STRIPS**

THE difference between hot rolled hoops and strips is not clearly defined in the trade. Hoops for general purposes vary in widths from ½ inch to 6 inches wide; on the Continent of Europe, from 12 to 150 millimetres wide. Greater widths than these are rolled for special trades—*e.g.*, gas tubes, and similar. In all cases hoops are deemed to be material which is produced to required widths in the rolling mill. The category of strips would include material which has been sheared to required widths from sheets (sheared strips). As, for some purposes, sheared strips are objectionable to the user from the nature of the edges produced by shearing, it is desirable for the buyer to take into consideration whether the widths are to be obtained in the rolling mill or by shearing. Hoops from the rolling mill are, furthermore, obtainable in much longer lengths than are practicable with any sheared strips.

Hoops may be divided into three classes:

1. Cooper's hoops, which are used for circling barrels, casks, etc., and which are cut to fixed lengths, splayed, nozed, and punched.

2. Special baling hoops, for putting round bales of wool, cotton, jute, etc., which are tougher and stronger than ordinary hoops, made of a special carbon steel, cut to long fixed lengths, and sometimes punched with holes to admit of baling studs.

3. Ordinary iron or soft steel hoops, which are used for packing cases and general purposes.

Hot rolled strip can be rolled in lengths of 150 feet and of 17 B.G. in thickness when 2 to 5 inches wide.

Hot rolled strips can be produced as thin plates in a "Universal" mill in widths from 16 to 25 inches, of ¼ inch thick and up, and in lengths of 85 feet.

The usual tolerance on widths by way of "Universal" rolling mill allowance is ⅛ inch over or under the prescribed width.

No material which is produced in the hot state can be obtained to the same degree of accuracy of size as material which is produced in a cold state.

In the practical operation of the hot rolling mill there are limits in sizes of length, width, and thickness imposed by the fall in temperature involved in the process. Although the tables of sizes show that hot rolled hoops can be produced as thin as 24 B.G., makers are seldom willing to supply thinner than 20 B.G. by straight hot rolling.

The permissible variations from prescribed width and thickness on hot rolled material which is thin in substance and rolled in long lengths follow the practical difficulties incidental to manufacture.

* By H. J. Skelton. This chapter is based on the Author's *Economics of Iron and Steel* (2nd edition).

Hot Rolled Iron Hoops (Limits of Sizes Rolled).

Width, Minima and Maxima, in Inches.	*Thickness in B.G. (Numbers).*	*Thicknesses in Decimals of an Inch.*
$\frac{1}{2}$ up to $\frac{5}{8}$	8 to 24	0·157 to 0·024
$\frac{3}{4}$,, $1\frac{1}{4}$	6 ,, 24	0·198 ,, 0·024
$1\frac{3}{8}$,, $1\frac{1}{2}$	6 ,, 23	0·198 ,, 0 027
$1\frac{5}{8}$,, $1\frac{3}{4}$	6 ,, 22	0·198 ,, 0 031
$1\frac{7}{8}$,, $2\frac{3}{4}$	6 ,, 20	0·198 ,, 0·039
$2\frac{7}{8}$,, 3	6 ,, 19	0·198 ,, 0·044
$3\frac{1}{8}$,, 4	6 ,, 18	0·198 ,, 0·049
$4\frac{1}{8}$,, 5	4 ,, 17	0·250 ,, 0·055
$5\frac{1}{4}$,, 6	4 ,, 17	0·250 ,, 0·055
$6\frac{1}{4}$,, $6\frac{1}{2}$	4 ,, 16	0·250 ,, 0 062
$7\frac{1}{4}$,, $7\frac{1}{2}$	4 ,, 13	0·250 ,, 0·088
$7\frac{3}{4}$,, $8\frac{1}{4}$	4 ,, 12	0·250 ,, 0·099

Hot Rolled Steel Hoops (Limits of Sizes Rolled).

Width, Minima and Maxima, in Inches.	*Thickness in B.G. (Numbers).*	*Thicknesses in Decimals of an Inch.*
$\frac{1}{2}$ up to 1	8 to 23	0·157 to 0·027
$1\frac{1}{8}$,, $1\frac{3}{8}$	6 ,, 22	0 198 ,, 0·031
$1\frac{1}{2}$,, $1\frac{3}{4}$	6 ,, 21	0·198 ,, 0·034
$1\frac{7}{16}$,, $2\frac{1}{4}$	6 ,, 20	0·198 ,, 0·039
$2\frac{3}{8}$,, $2\frac{3}{4}$	6 ,, 19	0·198 ,, 0·044
$2\frac{7}{8}$,, $3\frac{1}{2}$	6 ,, 18	0·198 ,, 0·049
$3\frac{5}{8}$,, $4\frac{1}{2}$	4 ,, 17	0·250 ,, 0·055
$4\frac{5}{8}$,, 5	4 ,, 16	0 250 ,, 0 062
$5\frac{1}{4}$,, 6	4 ,, 15	0·250 ,, 0·069

It is unavoidable that hooping, for example, which is rolled in long lengths, should differ in thickness at the beginning and end of an individual piece from the fall in temperature which has taken place during the hot rolling operation and the lowered temperature at which the rolled piece is finished.

Slight variations will occur over a number of pieces in a parcel which is nominally of the same width and thickness. The variations will be less in the case of hoops of 16 B.G., and thicker than in the case of hoops of 20 B.G. This remark applies to both width and thickness. As there are variations of quality of steel hoops for particular purposes, so there are variations in the standard of precision of workmanship according to the purpose for which they are destined. A more liberal tolerance would be accorded on rolled hoops produced for packing cases than for strips destined for the manufacture of close-joint tubing. It is not uncommon to find hoops $\frac{1}{32}$ inch (0·0312) over or under any prescribed width and variations in thickness between 0·003 and 0·005 inch.

Cold Rolled Steel Hoops and Strips.

A greater degree of accuracy and thinner material is obtainable by the cold rolling process, in which the raw material of the mill is the hot rolled material which has been produced to the limits of the practicable.

In this way, and for reasons of economy in weight, cold rolled steel hoops

for packing-case purposes are made in sizes from $\frac{3}{8}$ inch to $1\frac{3}{16}$ inches wide (0·375 to 1·875) in all gauges from 20 to 30 B.G. (0·039 to 0·12 inch thick). There are two grades of finish in such packing-case hoops, which are rolled from soft steel: (*a*) bluish scaling—unannealed; (*b*) black non-scaling—annealed.

Cold rolled strip for special purposes and in various degrees of hardness can be obtained from modern mills in all widths from $\frac{1}{4}$ inch up to 13 inches wide, and in all gauges. Cold rolled steel strip has been produced as thin as $\frac{1}{1000}$ inch. The prescribed thickness or gauge can be obtained within 0·0012 of an inch, or 0·03 of a millimetre in average work.

The various degrees of hardness in cold rolled strip are not obtained solely by the use of steel of varying carbons. Ordinary carbon steel products in bars and rods are graded by the bulk of steel-makers over a range as follows:

Dead soft steel	0·08 to 0·18 per cent. carbon.
Soft, mild, or structural steel	0·15 „ 0·25 „ „
Medium steel	0·20 „ 0·35 „ „
Half-hard steel	0·35 „ 0·60 „ „
Hard steel	0·60 „ 0·85 „ „

Hardness of different grades in cold rolled strip steel can be obtained by varying the amount of reduction in thickness at each passage of the metal through the rolls. The various " tempers " are dead soft, one-fourth hard, half hard, three-quarters hard, hard.

Dead soft would be used for deep stamping. Hard would be used without annealing in the flat state.

Cold rolled strip can be obtained in annealed, pickled, and bright condition, and is used for a multiplicity of trade purposes from making bright butt hinges to articles that are produced by folding, seaming, stamping, piercing, etc.

The long lengths—up to 200 feet, and even longer—which are put up in coils, are convenient for use in feeding automatic or semi-automatic machines.

The tolerances for various widths and thicknesses laid down in British Standard Specification No. 112 in connection with cold rolled steels for aircraft were as follows:

TOLERANCES FOR COLD ROLLED STRIP.

Thickness in Inches.	*Width in Inches.*									
	1 to under 2.		*2 to under 4.*		*4 to under 6.*		*6 to under 8.*		*8 to under 12.*	
	Tolerance.		*Tolerance.*		*Tolerance.*		*Tolerance.*		*Tolerance.*	
	Width.	*Thickness.*	*Width.*	*Thickness.*	*Width.*	*Thickness.*	*Width.*	*Thickness.*	*Width.*	*Thickness.*
0·092 and thicker	−0·0 +0·125	+0·0 −0·0015	−0·0 +0·125	+0·0 −0·002	−0·0 +0·125	+0·0 −0·003	−0·0 +0·250	+0·0 −0·003	−0·0 +0·250	+0·0 −0·003
0·091 to 0·048	−0·0 +0·125	+0·0 −0·0015	−0·0 +0·125	+0·0 −0·002	−0·0 +0·125	+0·0 −0·002	−0·0 +0·250	+0·0 −0·003	−0·0 +0·250	+0·0 −0·003
0·047 to 0·020	−0·0 +0·010	+0·0 −0·001	−0·0 +0·010	+0·0 −0·001	−0·0 +0·010	+0·0 −0·0015	−0·0 +0·015	+0·0 −0·002	−0·0 +0·015	+0·0 −0·002
0·019 to 0·010	−0·0 +0·010	+0·0 −0·001	−0·0 +0·010	+0·0 −0·001	−0·0 +0·010	+0·0 −0·0015	— —	— —	— —	— —

Bundling Hoops.

The methods adopted for bundling hoops for transport vary with different makers and for different markets or trades. Hoops that are ordered of fixed lengths are usually sent out in flat bundles, each bundle containing pieces all of one length. Hoops ordered of random lengths, or even of fixed long lengths, are folded into flat bundles, varying from 6 feet to 8 feet long.

Hoops in coils can usually be bought at a shilling or two per ton cheaper than similar hoops in folded bundles. The usual weights for bundles or coils are 56 pounds and 112 pounds each. The " ties " or pieces of wire by which the pieces are held together in bundles are weighed in with the hoops.

The productive capacity of the country for hoops and strips has been very considerably increased in the past few years, and the production in 1923 of 372,500 tons constituted a record. Imports are, in consequence, much less than before the War, and exports much higher. Imports and exports of hoops and strips in 1913 and 1923, together with the source of the imports and destination of the exports, are given below.

Exports of Hoops and Strips, 1913 and 1923 (Tons).

Exported to—	1913. *Hoops and Strips.*	1923. *Hoops, Baling, and Barrel.*	1923. *Hoops and Strips or Tubes.*
India and Ceylon	18,141	23,664	315
Egypt	6,117	9,048	22
South Africa	519	869	23
Australia	3,089	5,320	169
New Zealand	2,265	2,312	20
Canada	1,447	829	614
Other British Possessions	2,419	2,719	70
Total	33,997	44,761	1,233
Norway	124	365	57
Denmark	—	1,363	16
Germany	—	1,815	30
France	241	421	785
Portugal	554	591	7
Spain	1,042	569	214
China	2,376	3,931	103
Japan	514	2,996	692
Chile	254	595	—
Brazil	780	1,378	45
Argentine	521	1,511	6
United States	3,244	3,647	669
Other foreign countries	2,061	3,446	493
Total	11,711	22,628	3,117
Grand total (tons)	45,708	67,389	4,350
Value (£)	440,776	947,435	96,606

Imported from—	1913. Hoops and Strips.	1923. Hoops, Baling, and Barrel.	1923. Hoops and Strips for Tubes.
	Tons.	Tons.	Tons.
Sweden	2,172	—	116
Netherlands	411	48	252
Belgium	9,595	202	2,743
France	—	—	373
Germany	43,904	726	820
Luxemburg	—	36	10
U.S.A.	16,233	124	9,866
Other countries	89	28	14
Total (tons)	72,404	1,164	14,194

CHAPTER XV

*RAILS, TYRES, AND AXLES**

THE first rails used in this country were of wood, and connected the coal pits with the rivers, but they were naturally unsatisfactory, for the wood soon decayed or broke under the heavy loads. The first application of iron to rails was in 1630, when Beaumont nailed thin plates of malleable iron to the wooden rails which connected the coal pits of Newcastle to the river in those places where wear was greatest. In 1737, at Whitehaven, cast-iron plates were fastened continuously to the wooden rails, and rails wholly of iron became general after 1767. Cast-iron wheels were introduced in 1750, and in 1754 iron rails were laid for a tramway between Cole Brook and Horsehay. In 1776 the works at Coalbrookdale produced a flanged cast-iron rail laid on sleepers, but traction was rendered difficult by the dirt which collected on the surface. In 1779, therefore, William Jessop introduced a rail which got over this difficulty by having the wheels flanged instead of the rails. In 1800 the first car wheels were made of cast iron and used under small tramway cars. But here, again, the flange was on the rail, and not on the wheel, and it was not until about the middle of the century that iron car wheels with chilled treads and flanges were made.

In 1784 William Murdoch constructed the first locomotive made in England, but its height was only 14 inches, length 19 inches, and width over the driving wheels 7 inches. In 1804 Richard Trevithick built a locomotive capable of hauling 20 tons of iron, and in 1814 George Stephenson made a locomotive at Killingworth that would draw a considerable weight. In 1801 the Surrey Iron Railway was built; in 1821 the Stockton and Darlington obtained its Act; in 1825 other small lines obtained powers, and with the passing, after much opposition, of the Liverpool and Manchester Act in 1826, the railway era may be said to have begun. Soon after the invention of Bessemer steel, in 1856, the steel rail began to displace the iron rail, as it could not only be produced cheaper, but also had a longer life.

* Acknowledgments are due to Mr. E. H. Saniter for valuable help in the compilation of this chapter.

At one time rails were the largest single article of manufacture not only in Great Britain, but in all iron and steel making countries, and in 1881 over a million tons of rails were made both by Great Britain and the United States from Bessemer steel. Rails are now rolled from acid and basic open-hearth steel, as well as from acid Bessemer steel. They are classified according to the weight per yard (50, 60, 75, 80, and 100 pounds per yard, etc.), and according to whether they are bull-headed or flat-bottom rails. British Standard Specifications were issued for bull-headed and flat-bottom rails in 1922, and were No. 9 and 11 respectively in the Engineering Standards series. In view of the important uses for rails, and the serious consequences that might follow if defective material were supplied, the very greatest care is exercised in manufacture, and very stringent tests applied by way of analysis, tensile and drop tests. In order to prolong the life of the rails, the tendency now is to have a higher proportion of carbon, and railway rails are now made up to 0·65 carbon, and tramway rails to 0·7 carbon. In the evidence given by the British Rail-Makers' Association before the Board of Trade Committee appointed to consider the iron and steel trades after the War, it was stated that—

"Several trade associations have been formed from time to time with the object of assisting British steel rail manufacturers to secure as much export trade as possible, and a division of the home trade free from unnecessary competition. With this object in view, an agreement was made by the British Rail Makers' Association with the German and Belgian Associations in 1884, and with the German, Belgian, American, and French Associations in 1904, which latter was renewed in 1907 and again in 1912.

"Under these agreements Great Britain was allotted 65 per cent. of the pooled export trade in 1884, 37 per cent. in 1904, 37 per cent. in 1907, and 34 per cent. in 1912.

"These agreements represent an effort on the part of the British manufacturers to obtain for themselves a modicum of protection against aggressive competition by nationally protected manufacturers abroad. However, the results were disappointing, although by this means alone was the British rail trade kept alive for many years. The British share in the world's export trade in rails has been as follows":

Year.	*Total Export Trade in Rails of the World (Tons).*	*British Percentage.*
1884	756,412	71·81
1890	974,806	75·16
1900	981,678	38·09
1910	1,616,674	29·84
1911	1,566,955	23·95
1912	1,613,285	25·51
1913	1,594,421	31·88

Under the protection afforded by the Rail-Makers' Association, therefore, imports of rails were negligible before the War, and amounted to 14,161 tons in

1912, and 21,562 tons in 1913, compared with export figures of 407,175 tons in 1912, and 500,117 in 1913. There is no similar association with regard to tram rails, the output of which has steadily decreased from an average of 60,000 tons per annum in the four years ending 1905 to an average of 29,000 tons per annum in the four years ending in 1913. Imports rose from 3,800 tons in 1907 to 10,000 tons in 1913. The decrease in production is attributed to German bounty-fed competition in home and export markets. The Report just mentioned refers to a case where a British municipality deriving a great proportion of its rates and taxes from a local steel works ordered 1,100 tons of rails from a Belgian works at 15s. per ton less than the British price, and accepted delivery of these rails, although they had been once rejected by the Corporation Inspector.

The principal districts rolling rails are the North-East Coast, South Wales, Scotland, Sheffield, and the North-West Coast, but the production of rails since the War has not been anything like equal to the capacity for producing them. The country first attained an output exceeding one million tons in 1881, but in 1923 the output was only 637,700 tons. The markets for rails in 1913 and 1923 are shown in the following table:

Exported to—	*Rails* (*Railway*).		*Rails* (*Grooved for Trams*).	
	1913 (*Tons*).	1923 (*Tons*).	1913 (*Tons*).	1923 (*Tons*).
India and Ceylon	118,331	85,487	190	1,929
Straits Settlements	19,866	953	—	—
Egypt and Palestine	16,938	22,558	—	6
British East Africa	2,898	5,788	—	—
British West Africa	4,765	21,909	—	3
South Africa	66,331	30,777	4	629
Australia	134,946	27,635	1,383	9 458
New Zealand	28,176	16,332	2,272	1,503
Other British Possessions	5,285	4,619	61	1,017
Total	397,536	216,058	3,910	14,545
Sweden	—	658	115	323
Germany	—	24,235	—	—
Belgium	3	664	473	—
France	94	41	618	447
Portugal	333	2,012	—	—
Spain	453	1,516	—	176
China	22	362	—	840
Portuguese East Africa	19,619	2,208	—	2,201
Chile	1,595	1,411	—	205
Brazil	8,388	843	—	296
Argentine	54,591	5,718	160	52
Other South America	3,537	6,574	—	111
Other foreign countries	13,946	25,368	1,192	185
Total	102,581	76,610	2,558	4,836
Grand total (tons)	500,117	287,668	6,468	19,381
Value (£)	3,457,814	2,562,215	156,532	308,418

TYRES, WHEELS, AND AXLES.

The great centre for tyres, wheels, and axles is Sheffield, where more than one-half of the tyres, wheels, and axles produced in the country are made. A considerable tonnage is also made in other parts of Yorkshire and in Scotland.

Crank axles are invariably made from best quality acid open-hearth steel, and the best classes of straight axles and tyres are also made from acid open-hearth steel, but in these latter cases, where the work required is not so severe, basic open-hearth or acid Bessemer steel is sometimes used. The wheel centres are forged under very powerful hydraulic presses, and are then carefully machined to receive the steel tyres which are shrunk on to them. The process of fixing the wheels on to their axles is also carried out by hydraulic pressure, which varies according to the diameter of the axle. Railway wheels may have centres of the wrought iron open spoke, hot spoke, and cold spoke type, as well as of the hot solid spoke type, while railway wheel centres of the rolled steel basic type have largely superseded the teak centre wheels for railway carriages. Great care is exercised in the manufacture of tyres, wheels, and axles. In the case of tyres, the carbon content varies according to the grade of tyre required from 0·4 up to 0·75 per cent. The tyre has to pass a rigid drop test, while the tensile test varies from 45 to 75 tons. A further measure taken to ensure safety and prolong the life of the tyre is heat treatment, according to one of the following methods: (*a*) normalizing, which consists of reheating to a temperature above the critical range, maintaining this temperature a certain length of time, and then cooling in air; (*b*) sorbitizing by the Sandberg process, which consists in cooling the heated revolving tyre by means of atomized water and air; or (*c*) by oil treatment, where the tyre is heated to between 800° and 900° C., quenched in oil, and tempered. Crank axles are also either normalized or oil treated and tested by analysis, tensile, and cold bending; a drop test is also added in the case of straight axles. The ultimate stress required for crank axles is between 30 and 40 tons per square inch, and for straight axles 35 and 40 tons per square inch.

The production statistics do not differentiate between tyres, wheels, and axles for railway work and for other uses, but the following table gives the production in the last few years of forged tyres, wheels, and axles, and also for sleepers and fishplates.

	Forgings, Tyres, Wheels, and Axles. (*Tons*).	*Sleepers and Fishplates.* (*Tons*).
1919	139,000	41,500
1920	173,000	55,400
1921	93,500	53,400
1922	92,300	79,500
1923	194,800	124,300

Some firms make tyres and axles only, while others make complete wheels and axles. Of the production before the War a little over 40 per cent. was retained at home, 40 per cent. was exported to the Dominions, and the remainder went to foreign countries, of which the bulk went to British-owned railways in the Argentine and Brazil, so that nearly the whole production of the trade was within the sphere of British political or financial influences, and beyond this the trade had fallen to negligible proportions, owing chiefly to competition from Germany and the United States.

CHAPTER XVI

*INDUSTRIAL STANDARDIZATION: ITS IMPORTANCE TO THE BRITISH EMPIRE**

GENERAL.—Standardization carried out on a national basis is of paramount importance to the trade of the Empire. It leads to the setting up through co-operative effort of national specifications of the greatest importance to the home producers. They are equally important to engineers and traders in every part of the Empire.

USE OF BRITISH STANDARD SPECIFICATIONS IN COMMERCIAL TRANSACTIONS. —These specifications, known as the British Standard Specifications, and set up by the British Engineering Standards Association, or the B.E.S.A., as it is called, provide a most useful tool in the hands of the purchaser. They assist him in his communications with the producer. Although he may be thousands of miles away, they prevent fear of misunderstanding; by the terms and definitions which so many of the specifications give, they simplify correspondence in regard to tenders generally; in fact, the British standard specifications provide a means whereby commercial transactions can be carried on along the most efficient and economical lines.

ADVANTAGES TO THE PURCHASER.—By their use the purchaser can be certain of obtaining replacement of damaged parts through quick delivery from stock, and the interchangeability brought about through these specifications gives him an open market, as they have been agreed to by the industry as a whole.

EXAMPLES OF BENEFITS DERIVED FROM STANDARDIZATION.—The first piece of work carried out by the B.E.S.A., this national organization, was the simplification of steel profiles. Previous to this work there were several hundred rolls in existence, and the sections were first reduced to 175, and more recently to 113. This revision has brought about marked economy all round, estimated at 5s. per ton to the manufacturer.

Another piece of work of great importance has been the standardization of railway and tramway rails. In the case of the tramway rails the sections have been reduced from 74 to 4. In regard to the railway rails the adoption of British standards has not perhaps been quite so rapid as in the case of the tramway rails. The present standards, however, for bull-head railway rails, which are being adopted by practically all the railway groups, are bound to bring about considerable economy all round. Also the revised sections for flat-bottomed rails should prove of material assistance to our steel-makers in competing in the world's markets.

The importance to the steel industry of these pieces of standardization shows clearly the beneficial results which can be expected from putting into operation a wide and well-thought-out scheme of standardization. It is essential, however, that whatever is done shall have the fullest co-operation and backing of industry as a whole.

* By C. le Maistre, C.B.E., Secretary, British Engineering Standards Association.

PRIMARY OBJECTS.—One of the primary objects of standardization, or unification, as I prefer to call it, is to save time, trouble, labour, and money. The benefits accruing from such work, when carried out through a co-operative plan, are felt throughout the multitudinous branches of industry touched by any single piece of standardization.

THE EFFECT OF STANDARDIZATION.—Its effect is to establish through all commercial transactions both simplicity, honesty, and confidence, where formerly misunderstandings were so rife, and it also gives protection against unfair competition.

NEED FOR CO-OPERATION.—It calls for the closest co-operation on the part of both producers and users, for whatever recommendations are put forward must be both sound and economical. They must conform generally to the practice of the manufacturers, as well as give the buyer his full requirements. Unless these basic principles are kept in full view, failure is likely to result. For these reasons, as much as for any other, industrial standardization, to be really effective in its assistance to industry, should be carried out on a national basis rather than by individual firms to satisfy their own particular purpose or convenience.

UNIFYING THE NEEDS OF INDUSTRY.—Again, in unifying the requirements of industry the basis of the proposals for national standards should be taken from what is best in present practice without attempting to set up an ideal which may be quite uneconomical for industry to adopt. The greatest care, on the other hand, has to be exercised to ensure that the average is not depressed—that is to say, that the poorer quality products are not accepted as the basis, for in that case also the resulting standards would be quite uneconomical and unsound.

COMMUNITY INTEREST OF PRODUCER AND CONSUMER.—The B.E.S.A. has always placed in the forefront of its activities the community interest of producer and consumer, who are brought into consultation at the very commencement of any work of standardization. This, in fact, is the corner-stone of the movement. It is doing much to facilitate production, to simplify tendering, and especially to assist British manufacturers to meet competition in the world's markets.

LOCAL COMMITTEES ABROAD.—Further, to assist British export trade, local Standards Committees of British engineers and traders have, with the assistance of the Government and the various British Chambers of Commerce abroad, been set up in the chief trading centres of the world. It is hoped in this way to keep in close touch with the requirements of foreign markets. These local committees, having a direct and intimate knowledge of local conditions, are in a peculiarly good position to advise the home Committee as to any modifications needed in the British standards to meet the local conditions. These committees deserve the most cordial support of British firms, especially of those with agents in foreign countries.

The Association has also done a great deal to familiarize foreign purchasers with British standards, for it has translated into foreign languages a considerable number of the most important British standard specifications, and these have been disseminated in considerable quantities through the agency of these local committees.

B.E.S.A. ACTS ON OUTSIDE PRESSURE.—It cannot be too widely known that the B.E.S.A. does not embark on standardization on its own initiative. It generally acts at the specific request of some authoritative body, such as a repre-

sentative trade organization, a technical society, or a Government Department, but the important fact is, that it waits for pressure from outside. Moreover, it assures itself, by the convening of a representative conference of all interests concerned, that there is a consensus of opinion favourable to the proposed work being carried out, and that it is to fulfil a recognized want. Not until it is assured that this is the case does the main committee appoint a sectional committee to study any subject.

GROWTH OF THE ORGANIZATION.—The organization, which was instituted in 1901 with one committee, has now grown to a movement in the closest touch with scientific, technical, and industrial progress, covering most branches of the engineering and allied industries, with over 2,000 engineers and business men up and down the country, who give their time and experience to this work without fee or recompense.

CENTRALIZATION OF WORK.—The fact that the work is carried out under one roof presents distinct advantages; it offers to industry a co-ordinating influence which could not be obtained in any other way. The centralization enables standardization to be carried out far more economically than would be the case if work of the same nature were carried out with the same efficiency by any single branch of industry acting on its own. It provides a highly experienced and specialized staff, and it is able to prevent a very great deal of overlapping of effort. It also offers the widest possible publicity for the standards issued.

Carrying out the work in this way does not imply that there is no decentralization. On the contrary, the preparation of many of the proposals which come forward as a basis for standardization can be carried forward much more economically by the co-operating bodies, who are sometimes, moreover, in a better position to discipline their own members than is the central organization itself.

ECONOMICAL BASIS ESSENTIAL.—To be of lasting value industrial standardization must have an economical basis, and this point is never lost sight of in the work, which is resulting in considerable national economies through the elimination of waste. Everyone nowadays is agreed upon the absolute necessity of reducing the multiplicity of patterns and designs for one and the same article, as this so hampers the producer in that he is unable to manufacture in any quantity or to reduce his overhead charges.

NATIONAL IMPORTANCE OF STANDARDIZATION MORE AND MORE RECOGNIZED.—The national value of industrial standardization is becoming more and more recognized, as is evidenced by the fact that there are now some eighteen standardizing bodies in existence, one in each of the following countries:

America.	Denmark.	Italy.
Austria.	France.	Japan.
Australia.	Germany.	Norway.
Belgium.	Great Britain.	Russia.
Canada.	Holland.	Sweden.
Czecho-Slovakia.	Hungary.	Switzerland.

These standardizing bodies have, in many cases, dipped considerably into the experience of the B.E.S.A., and whilst standardization in the various countries,

due to national characteristics, is not at present carried out entirely on similar lines, the time is rapidly approaching when the industrial point of view will prevail everywhere.

INTERNATIONAL AGREEMENT.—In some branches of industry, not by any means in all, international agreement is becoming of vital importance. In this connection it is interesting to note that interchange of ideas is frequently taking place between various branches of industry in the different countries through the secretaries of these standardizing bodies, who are now in fairly close correspondence with each other.

In so far as the electrical industry is concerned, the electrical sections of these standardizing bodies are the national committees of the international commission dealing with electrical work, and known as the International Electrotechnical Commission, or the I.E.C., which was formed in 1906, and now has twenty-four countries affiliated with it.

In the electrical industry the fundamental units and standards are the same all over the world, and it is therefore not so difficult as in other branches of industry to carry forward a certain measure of international agreement on industrial matters. In the mechanical world, however, the serious difficulty of the metric system at once becomes evident. Moreover, there is the difficulty, in all cases, of language and racial differences, and desirable as it may be to obtain international agreement on standardization in the engineering industry in general, because of these difficulties, it can only proceed slowly and with the greatest caution.

Again, international agreement, to be effective, should deal only with the larger and more general problems, leaving details to be dealt with by the National Standards Committees, and in every case proposals for international standards should be very thoroughly discussed in the different countries before they are put forward for international agreement.

One of the most serious problems in international work is the question as to whether agreement on international standards should precede agreement on national standards; in certain cases it may be possible to do this, but in the majority of cases industry appears to feel it more desirable to put its own house in order before attempting international agreement.

CONCLUSION.—There is no doubt that for the engineering industry of this country to prosper at home and to retain and enlarge its markets abroad it will have to engage on a wider scheme of industrial standardization than is the case at present, especially in the steel industry. Both the United States of America, as well as Germany, and to a lesser degree other countries, are making tremendous strides in this direction. Happily there are many signs that the utility of industrial standardization as implying the bringing of industrial people together to unify their needs through simplification and the elimination of waste is being increasingly realized in this country also. Moreover, as time moves on, people are more and more willing to sink their individual differences with a view to benefiting the many, and when one considers the public-spirited manner in which this standardizing movement is supported, one realizes what a debt the nation owes to our engineers and business men for the part they are so willingly taking in this national work.

CHAPTER XVII

CONCLUSION

WE have now made a very rapid and summary survey of the British iron and steel industry as it stands at the present day, but the question naturally arises, What of the future? Great Britain, the pioneer in the iron and steel industry, found itself surpassed in production by the United States in 1890 and by Germany some years later. The supremacy of the United States can hardly be expected to be challenged, but the changes due to the Peace Treaty place Great Britain, France, and Germany in the position of competitors for the second place. This position was attained by Great Britain in 1923 owing to a special combination of circumstances, and the question arises as to how it may be maintained. Before turning our attention to the position of each of our competitors a word might be said as to the demand for iron and steel. With the world starving for iron and steel in order to repair the ravages of war and in order to make up the leeway caused by the difficulty of obtaining steel for any but destructive purposes during five years, it may seem surprising that the production of iron and steel in no year since the War has equalled the production in 1913, the main reason being that the purchasing power is not available to make this demand effective. In this respect the post-war period resembles the decade 1810 to 1820, which was affected by the post-Napoleonic war depression and, according to Eckel, was the decade which saw the lowest rate of increase of the world's iron industry of any between 1800 and 1910, and even this low rate (33 per cent.) was not reached between 1910 and 1920. When confidence is once more restored, however, it is safe to say that the demand for iron and steel will equal, if not exceed, the capacity to supply, even though this has been increased by the war extensions. At the moment, however, there is a very large increased capacity to meet a very much reduced effective demand, with the consequence that very severe competition is being experienced between Great Britain, France, Germany, and Belgium. Competition is no new phase, for, as the late Mr. Jeans pointed out twenty years ago, there is scarcely an industry in the world that is more liable to and affected by foreign competition than that of iron and steel, for their products are universal needs, and are produced on a very large scale. Demand has not been regular; it has been stimulated first by one reason and then by another. Capital has been expended and plant extended only to find that when the want that provided the stimulus has been supplied, capacity is in excess of demand, and it is some years before the demand, either by a natural gradual increase or under pressure from a new stimulus, again overtakes supply. Mr. Carnegie was therefore quite right when he said that the iron trade is either prince or pauper.

The various ups and downs which the industry experienced from 1870 onwards were very succinctly put in Mr. Jeans's book on the iron trade, which we cannot do better than quote:

"About 1869 extensive railway building operations were adopted on the Continent, but these were checked in July, 1870, by the declaration of war between France and Germany. When peace was concluded in the following year both nations desired to proceed with their railway and other improvement schemes; and as they had not the necessary resources for providing the required materials very large contracts were placed in Great Britain, which was the only country that at that time was in a position to execute them. The almost simultaneous expansion of general trade and railways in other countries caused the nearest approach to a coal and iron famine that we have ever known. In 1871 there was a rapid rise in prices, and in 1872 and 1873 the general range of values for all commodities was higher than it has ever been since. The prices of iron ore, coal, coke, pig iron, and manufactured iron and steel of all kinds rose from 100 to 200 per cent. The cost of labour rose very largely at the same time, until the wages of coal miners and ironworkers were more or less doubled in amount. This movement led to much trouble in the years that immediately followed. About 1874 trade became depressed, and the depression lasted until 1879. Many strikes took place in the interval, following chiefly on demands for reduced wages. The situation was rendered more difficult by the development, almost for the first time in our modern industrial history, of foreign competition which, beginning with Belgium, extended in course of time to Germany, France, and other countries. Between 1877 and 1879 this competition was much felt. In 1879, however, trade took a turn for the better, and the improvement continued until the end of 1880, during which time prices rose to a higher level than had been known since 1873. The next few years were marked by notable depression, especially the years 1885 to 1887. In that time many failures took place, prices fell to an almost unknown level, exports fell off considerably, money was tight, wages were low, and all the usual accompaniments of severe depression were rampant. This was perhaps, on the whole, the most dismal period that the iron and steel trades have ever known. It coincided not only with a great increase in foreign competition, but with striking and revolutionary changes in processes and products. The more important of these were the substitution of steel for iron in respect of shipbuilding, and many other applications, and the increasing adoption and success of the open-hearth process of steel manufacture, initiated and carried to a practical issue by Messrs. William and Frederick Siemens.

"Again, in 1889, almost exactly ten years after the previous reaction had begun, business took a turn for the better, and during that year and the year 1890 there was not much to complain of. Foreign trade improved, home demands increased, and prices all round advanced. The improvement, however, was short-lived; in 1891 it had clearly spent itself. In 1892 trade was again seriously depressed. In the following three years it was unsatisfactory, but in 1896 it took a change for the better; and the next five years witnessed perhaps the longest and, on the whole, the most satisfactory revival that the iron trade has ever known. During this period the make of British pig iron increased from 7·7 to 9·4 million tons. This advance coincided with a corresponding increase from 9·4 to 13·6 million tons in the case of the United States, and from 5·4 to 8·1 million tons in the case of Germany, while nearly all other iron-making countries had similar records.

The make of pig iron throughout the world in these five years increased from a little over 30 to about 40 million tons."

The present phase of Continental competition is therefore no new one nor one which will find the iron and steel manufacturers of Great Britain without a remedy. The most formidable rival which Great Britain will be faced with in the future is probably Germany. Germany is making great efforts to overcome the handicap of defeat, and especially that imposed by the loss of Lorraine ore. She is also assisted by works whose technical equipment is second to none and whose capital charges are certainly much reduced.

Although the iron and steel capacity of Belgium is no more than one-fourth that of this country, it can nevertheless prove a very formidable competitor. Belgium was, in fact, our first real competitor, and remained so until about 1875. Belgium depends to an even greater extent than does Great Britain on export trade, and in competition with Great Britain is favourably situated by reason of low labour costs and the modern plant which has replaced that destroyed during the War. Export is also encouraged as part of the national policy, the Belgian Government guaranteeing the payment to Belgian exporters of one-half the value of their overseas contracts. With these advantages Belgium has been able to do a big export trade in 1923 in spite of her difficulties with regard to fuel owing to the Ruhr occupation, and her exports to Great Britain were actually higher than before the War.

Before the War France scarcely counted as an exporter of iron and steel, her exports being only about 10 per cent. of the exports from this country, but under the Peace Treaty France obtained the magnificently equipped iron and steel plants of Lorraine, which added considerably to her capacity and rendered it necessary that she should become an exporter of iron and steel. That her exports have not hitherto been commensurate with her increased capacity has been due first to the fact that much of her original plant in the North and East had been destroyed by the Germans; secondly, that coal and coke was not forthcoming from Germany under the terms of the Peace Treaty in sufficient quantities; and thirdly, that the business of exporting iron and steel was to a large extent new to France. These difficulties have now been practically overcome, for the rebuilding of the destroyed works is being rapidly completed, selling organizations to deal with the export trade have been discussed, and the recent agreement with the Germans has secured the necessary fuel supply.

American productive capacity was increased by 50 per cent. during the War, during which she also developed a considerable export trade in iron and steel. For the last two years, however, her home demand has been so great that the United States has not had to pay much attention to the export trade, but it is recognized that the home demand may not always be sufficient to absorb the whole of the productive capacity, and it is part of the policy of the United States Steel Corporation to reserve a definite portion of its output for export. While, owing to costs of production, the competition from America is not comparable with that from Belgium, France, and Germany, it is clear that at any time it may become more active.

Foreseeing the recrudescence of foreign competition as soon as the War was over, the expert committee which considered what would be the position of the iron and steel trades after the War, and reported in 1917, made certain recommendations, the chief of which are given below:

1. That an organization be formed, comprising users of iron ore, and others interested in and essential to the conduct of the trade, to undertake the import and distribution of foreign ores in Great Britain, and acquire interests in ore properties abroad, and that such organization should receive Government financial assistance, if necessary.

2. That iron and steel manufacturers should associate themselves for the purposes of export trade, and should form common selling organizations by the extension and consolidation of associations which already exist.

3. That an organization—co-operative in character—be formed among British manufacturers for the purpose of obtaining adequate supplies of suitable iron ore. Ultimately this organization might become the owner of large deposits or gain absolute control of them in such a way as to ensure continuous and uninterrupted supplies of raw material to the British manufacturer. Further, an investigation should be undertaken by competent engineers of the hitherto unexploited deposits of iron ore in the United Kingdom.

4. That a national selling organization should be formed for the purpose of marketing British iron and steel products in an efficient and economical manner. This organization should comprise a central body with separate sections, each dealing with the products controlled by existing associations. This selling association would necessarily undertake the distribution of orders so as to reduce the cost of production to the lowest limit by keeping individual works running as long as possible on standard products.

5. That British iron and steel manufacturers should be urged to form combinations for the purpose of laying down large and well-designed new units, for cheap production upon modern lines. The companies formed to build and work these plants should, if necessary, receive financial aid from the Government, especially in view of the high cost of laying down large plants to-day. This high cost is largely due to the artificial inflation of prices by war conditions, and a fall in prices would involve heavy depreciation of capital values.

6. The expansion of the industry upon this scale will involve a demand for materials and labour which can only be met by careful conservation of existing resources. No doubt by the natural operation of demand a larger proportion than hitherto of coking coal will be reserved for home use; but it would be preferable to reinforce the natural operation by bringing into intimate relation the iron and steel manufacturer and the owner of coking coal.

7. That all labour employed in the iron and steel industries should, as far as possible, be brought together under the authority of a single trades union.

8. That anti-dumping legislation be introduced in the United Kingdom, similar to that in force in Canada.

9. That no iron or steel shall be imported into the United Kingdom which does not bear clearly and indelibly a readily recognizable mark of origin.

Although it is recognized that there are gaps resulting from the necessity of

compressing a great subject into the space of a single volume, it is hoped that this survey will enable the reader to have a better appreciation of the potentialities and difficulties of the British iron and steel industry.

From this brief review certain conclusions may be drawn. The increased world capacity for production means the need for increased outlets.

The United Kingdom and the United States have an increased surplus for export, but whether the United States will build up an export trade commensurate with the one she attained during the War is a question to which no definite answer can yet be given. Germany, with a diminished exportable surplus, may be expected to concentrate on the finishing industries, and will prefer to export highly finished products in place of the pig iron and semi-finished steel which she sent abroad in such quantities prior to the War. France now takes a prominent place among the exporting nations, and it is probable that France will be content for some time to export pig iron and semi-finished steel. The fundamental physical conditions, however, which enabled Great Britain to continue making steel before the War remain substantially unaffected. We are the only steel-producing country with suitable coal supplies on the coast to which foreign ore can be brought by sea and the product reshipped.

APPENDIX

THE PRODUCTION OF PIG IRON AND STEEL IN THE UNITED KINGDOM, UNITED STATES, GERMANY, AND FRANCE IN 1870, 1880, 1890, 1900, 1910, 1920, AND 1923 (IN THOUSANDS OF TONS).

	Pig Iron.				Steel.			
Year.	*United Kingdom (Tons).*	*U.S.A. (Tons).*	*Germany (Metric Tons).*	*France (Metric Tons).*	*United Kingdom (Tons).*	*U.S.A. (Tons).*	*Germany (Metric Tons).*	*France (Metric Tons).*
1870 ..	5,963	1,665	1,262	1,178	—	—	—	—
1880 ..	7,749	3,835	2,468	1,725	1,295	1,247	733	—
1890 ..	7,904	9,203	4,100	1,962	3,579	4,277	2,232	683
1900 ..	8,960	13,789	7,550	2,714	4,901	10,188	6,646	1,565
1910 ..	10,012	27,304	13,111	4,038	6,374	26,095	13,699	3,413
1920 ..	8,035	36,926	6,387	3,434	9,067	42,132	8,363	3,050
1923* ..	7,438	40,361	4,000	5,432	8,489	43,239	5,000	5,109

* Provisional figures.

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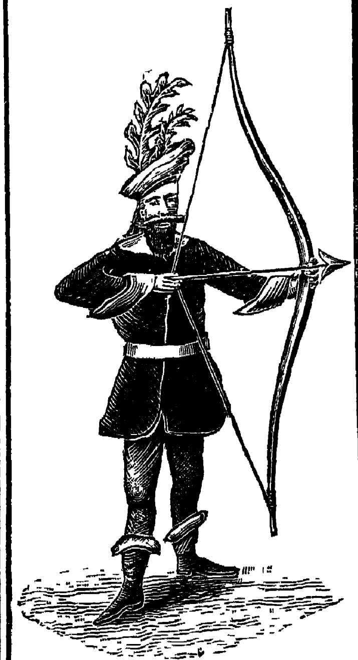

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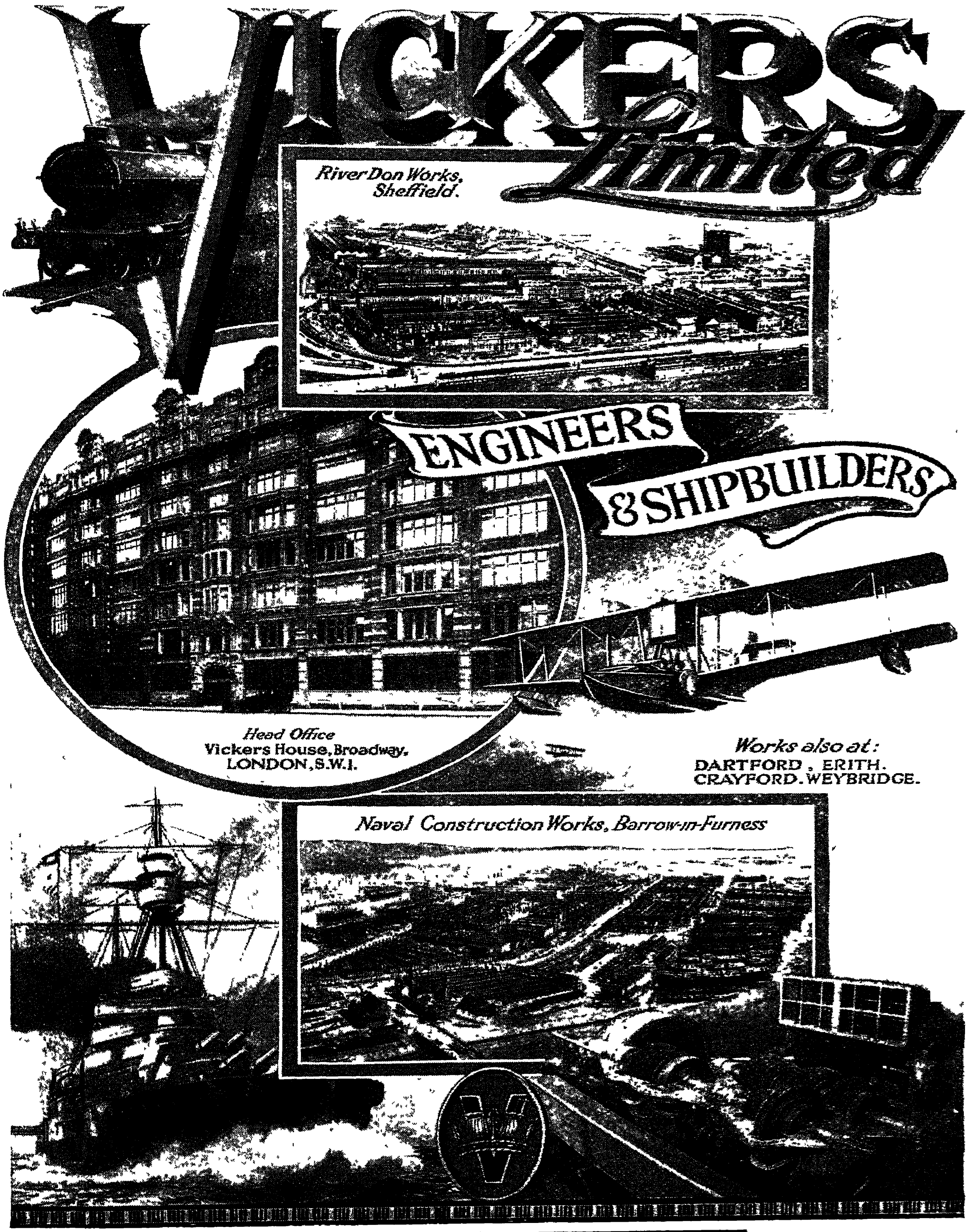

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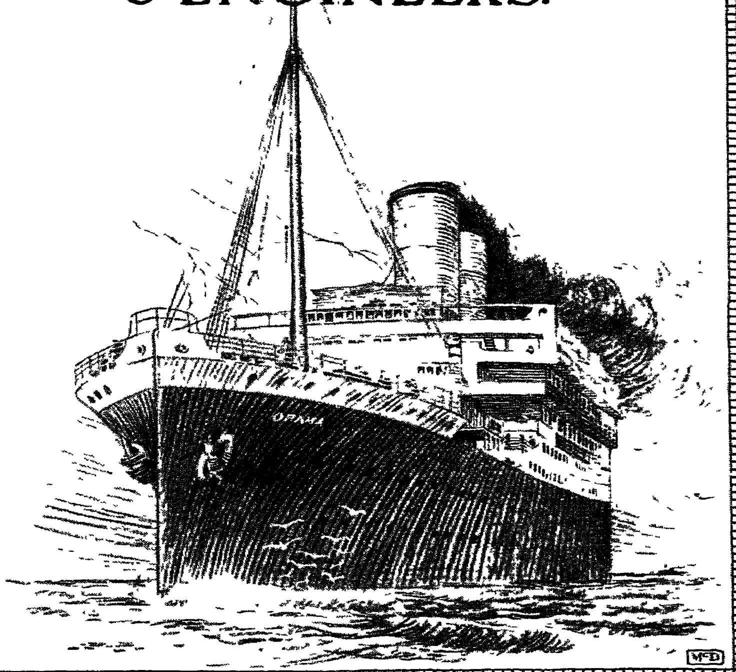

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